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Leslie Population Estimation for Turkish Crayfish (*Astacus leptodactylus* Esch., 1823) in the Keban Dam Lake, Turkey

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Abstract

The population size was researched by using Leslie method on the zones of Keban Dam Lake where crayfish is fished for commercial purposes. The data were compiled by using effort expended and catch obtained by 28 fishing boats during 2012 crayfish fishing season. 28 fishing boats fished 16,867 kilograms of crayfish during the fishing season by using 45,600 pieces of crayfish fyke nets. It is determined that the quantity catch per unit effort (CPUE) varies between 2.74 to 6.35 kg/100 fyke nets/week during the 9 weeks fishing period. The population size at the beginning was estimated to be 28,450 kg (at minimum legal length of ≥10 cm). The 95% confidence interval of this estimation was calculated to be 25,607-32,533 kg. Similar researches on crayfish populations concluded that removal method can offer very important details.

Keywords: *Astacus leptodactylus*, Leslie method, population size, catch per unit effort, cumulative catch, Keban Dam Lake (Turkey).

Keban Baraj Gölü (Türkiye) Kerevitlerinin (*Astacus leptodactylus* Esch., 1823) Leslie Metodu ile Populasyon Tahmini

Özet

Keban Baraj Gölü'nün ticari kerevit avcılığı yapılan bölgelerinde Leslie metodu kullanılarak populasyon büyüklüğü araştırılmıştır. Veriler, 2012 kerevit avcılık sezonunda kerevit avcılığı yapan 28 balıkçı teknesine ait av çabası ve av miktarı değerlerinden oluşmaktadır. Av sezonu süresince 28 balıkçı teknesi tarafından 45,600 adet kerevit pinteri kullanılarak 16,867 kg kerevit avlanmıştır. Birim çabadaki av miktarının 9 hafta süren av sezonu içerisinde 2,74 ile 6,35 kg/100pinter/hafta arasında değişiklik gösterdiği belirlenmiştir. Başlangıçtaki populasyon büyüklüğü (minimum av boyunda, ≥10 cm) 28,450 kg olarak tahmin edilmiştir. Bu tahminin %95 güven aralıkları 25,607-32,533 kg olarak bulunmuştur. Benzer kerevit populasyonlarının araştırılmasında azaltma metodunun çok önemli veriler sağlayabileceği sonucuna varılmıştır.

Anahtar Kelimeler: *Astacus leptodactylus*, Leslie metodu, populasyon büyüklüğü, birim çabadaki av miktarı, toplamalı av, Keban Baraj Gölü (Türkiye).

Introduction

The narrow-clawed crayfish (popular name "Turkish crayfish") *Astacus leptodactylus* is a native freshwater crayfish species found in Turkey. It occurs naturally in Eğridir, Beyşehir, Akşehir, Eber, Çivril, Apolyont and Manyas Lakes. In addition to these populations, this species has been stocked in many freshwater systems throughout Turkey, because of its economic importance and to restore crayfish stocks previously affected by a crayfish plague (*Aphanomyces astaci*) (Harlioğlu and Harlioğlu, 2004). One of these reservoirs is that Keban Dam Lake (Yüksel and Duman, 2011 and 2012).

Keban Dam Lake, which is one of the very few large dam lakes of Turkey and located on an area of 68,731 hectares, has an outstanding fisheries potential. There are 28 species of fish from 7 families inhabiting the Keban Dam Lake (Yıldırım *et al*., 2010). Besides, crayfish stocked in the dam lake afterwards adapted to the environment and became the most valuable product fished for commercial purposes in the dam lake. Ensuring continued and steady production of crayfish in Keban Dam Lake depends on through understanding of the population and fishing activities should be organized accordingly (Demirol, 2013; Demirol and Yüksel, 2013).

Estimation of the density of natural crayfish populations requires a methodology designed to assess the population size within a known area. Estimation of population size can be carried out either in terms of relative abundance, using CPUE (catch per unit effort) data or as absolute abundance, using census methods or mark-recapture techniques. It is not always possible to estimate the population density directly. Sometimes researches have to make to with just a relative measure or index of density based on animal signs. Therefore, CPUE is the most common method to investigate populations and to arrange fishery activity. CPUE is a measure of relative abundance. If yield could be forecast, the data could be used by authorities to reduce exploitation by reducing legal season or consider other regulations to protect the crayfish (Balık *et al*., 2002).

Crayfish populations in smaller aquatic environments tend to rapidly suffer from pressure of fishing. Generally, remedying this impact either takes a long time or is not possible. Therefore, fishing must be regulated to data of population size. The Leslie method can be used to estimate the size of a crayfish population by regressing catch per trap haul on cumulative catch of the fleet at several time intervals within a fishing season (Miller and Mohn, 1993).

In the recent years, Fisheries Cooperatives have been terminating crayfish fishing activities in the Keban Dam Lake before the end of fishing season because the number of crayfishes above the legal length has drastically decreased in the fishing composition. This fact emerged the idea that Leslie regression model (Leslie and Davis, 1939) known as removal method will be appropriate for studying this population. This study aims at being a pioneer figure in researching on similar populations rapidly suffering from pressure of fishing.

Materials and Methods

Keban Dam Lake

The Keban Dam is located on 45 kilometers north-west of Elazığ province and 65 kilometers north-east of Malatya province and constructed in Keban town which is situated on 10 kilometers south-west of the area where Karasu and Murat rivers intersect. The lake basin of the dam is located between 38º30'60" and 39º30'80" longitudes and 38º30'73" and 39º00'45" latitudes. The fishing activities on the dam lake are divided into 16 different fishing places (Yıldırım et al., 2010). This study is about 4 fishing places (Kemaliye, Keban, Ağın and Çemişgezek) located in the dam lake and used for fishing crayfish for commercial purposes (Figure 1).

Study Period and Collecting Data

The study was focused on the actual period of commercial fishing within 2012 crayfish fishing season, namely from July 5 until September 5. First of all, it was determined that there are total 28 boats fishing crayfish in the dam lake. The quantity of crayfish caught each week was determined by visiting the points of going ashore because fishermen leave their fyke nets in water for a week and go ashore on certain days of a week. Besides, the number of fyke nets used by all fishers during the fishing season was noted for determining the fishing effort.

Catch Per Unit Effort (CPUE)

The amount of catch per unit effort (CPUE) for

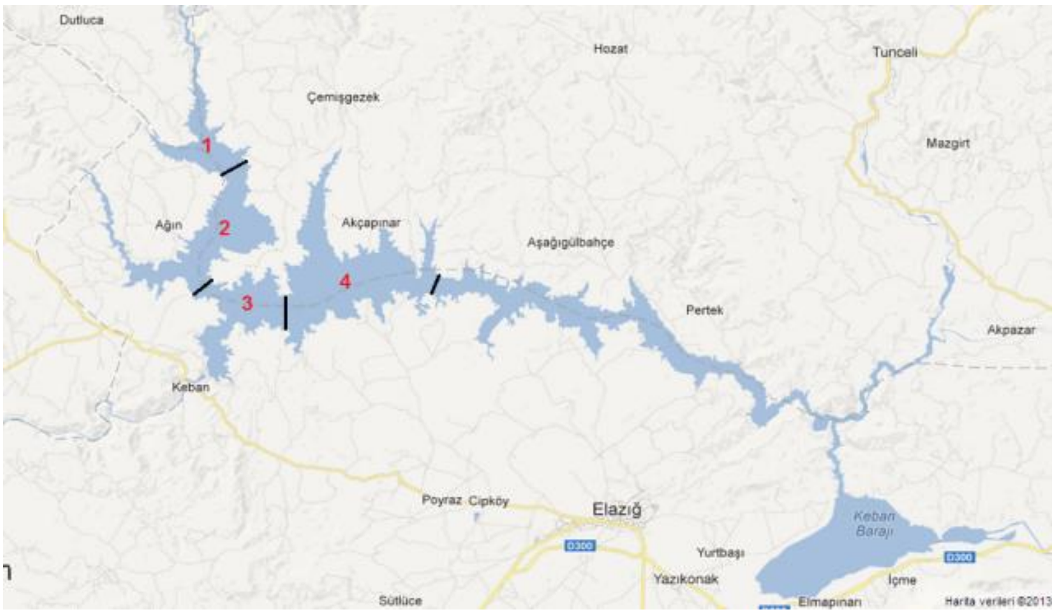

Figure 1. Keban Dam Lake (1: Kemaliye, 2: Ağın, 3: Keban, 4: Çemişgezek) (Google, 2013).

per fyke net was calculated using the following formula (Hyvärien and Salojärvi, 1991; Balık and Çubuk, 2001):

$$CPUE=\sum (Y/n)N \quad [1]$$

In the formula;
Y: The amount of catching crayfish (kg),
n: The number of using fyke net,
N: The number of trials.

10 cm and longer crayfishes at legal length were taken into consideration while determining the quantity catch per unit effort. The quantity catch per unit effort was described as “kg / 100 fyke nets / week” since fyke nets were kept in water for 7 days during each fishing operation.

Leslie Regression Model (Depletion Model)

The Leslie regression model (Leslie and Davis, 1939) was used to estimate the population size of legal minimum catch length of the *Astacus leptodactylus* in the Keban Dam Lake. The Leslie method uses the relationship between catch per unit effort and stock abundance (Knight and Cooper, 2008). The method of Leslie requires that three assumptions are satisfied: (1) the population is closed; (2) probability of each individual being caught in a trap is constant throughout the experiment (3) all individuals have the same probability of being caught in sample *t*. The data required for Leslie model are as follows:

C_t: catch taken during time interval *t*
K_t: cumulative catch from the start up to the beginning of sample time *t*
f_t: fishing effort during time interval *t*
N_o: original population size (at time t=0)
q: catchability coefficient
C_t/f_t: catch per unit effort during the interval *t*

Under the assumptions listed above, a regression plot of catch-per-unit-effort (C_t/f_t, Y-axis) to cumulative catch (K_t, X-axis) gives a straight line (Equation 2).

$$\frac{C_t}{f_t} = qN_0 - qK_t \quad [2]$$

In this equation as known Leslie regression model, the slope of regression line is an estimation of catchability, *q*. The Y-axis intercept is the product of the original population, N_o, and the catchability, *q*. The slope and intercept of this straight line was found using linear least-squares technique. The original population size was estimated from equation (3).

$$N_0 = \frac{intercept}{|slope|} = \frac{a}{|b|} = \frac{qN_0}{|q|} \quad [3]$$

Confidence limits for the estimate of *q* are the same with slope (b). Confidence limits for the estimate of No for any level of probability were calculated as roots of the equation 6.4 in Ricker (1975) (Equation 4).

$$N^2(q^2 - t_p^2S_{yx}^2c_{22}) - 2(q^2N_0 - t_p^2S_{yx}^2c_{12})N + (q^2N_0^2 - t_p^2S_{yx}^2c_{11}) = 0 \quad [4]$$

Where:
$c_{11} = \sum X^2 / n\sum x^2$
$c_{12} = \sum X / n\sum x^2$
$c_{22} = 1 / \sum x^2$
t_p = The *t* value corresponding to a given probability P for n - 2 degrees of freedom, found from a *t*-table such as Snedecor's (1946) table 3.8.
n = The number of days of fishing.

Results

Although crayfish fishing season at Keban Dam Lake was approximately 18 weeks (between July 1 and October 31), fishing activities were interrupted at the end on 9th week in 2012. The fishing effort initially started with 28 fishing boats and 45,600 fyke nets decreased gradually and reduced down to 12 fishing boats and 21,300 fyke nets on the last week. Likewise, crayfish catches and catch per unit effort (CPUE) started to decrease after the first week and continued to decrease until the last week. The catch per unit effort was respectively 6.28 and 6.35 kg/100 fyke nets/week on the 1st and 2nd weeks whereas the number reduced down to 2.74 kg/100 fyke nets/week on the last week (Table 1). It is observed that the crayfish caught are of legal fishing size (10 cm and above).

Estimation of the population size of crayfish (≥10 cm, minimum catch length) in the Keban dam lake was calculated according to the Leslie regression model (removal method) using the data obtained as a result of the fishing performed by fishing boats in the dam lake in the course of nine weeks. The data used in the calculations such as the amount of catch, the fishing effort spent, the amount of catch per unit effort, and the amount of cumulative catch are provided in Table 1. The fishing effort data used for calculations represents the amount of fyke nets used by fishers. Each 100 fyke nets kept in water for a week for fishing purposes was considered as a set of fyke nets.

The initial population size of crayfish (≥10 cm, minimum catch length) in the Keban Dam Lake was estimated to be 28,450 kg. Upper and lower limits of confidence for the probability level P=0.05 were calculated to be 25,607 kg and 32,533 kg, respectively. The regression equation, in the original symbols, was found to be C_t/f_t=6.5718-0.000231*K_t. Linear regression plot and equation are provided in Figure 2.

Discussion

Although there are 28 species of fish in Keban Dam Lake, crayfish is considered to be the most valuable species in terms of economy. The annual crayfish production in the dam lake varies from 3,000 kg to 35,000 kg from 1994 until 2013. 2012 crayfish fishing season lasted in 9 weeks and 16,867 kg of crayfish were caught in total. Fishing effort and number of crayfish caught decreased towards the last week. This situation is emerged because the number of crayfish at minimum legal length decreased within the population as a result of the fishing activities. The Leslie regression model used for the estimation of the population size depends on the principle of decreasing population due to fishing activities performed in the lake (Mohn, 1980; Peterson *et al*., 1980; Akamine *et al*., 1992; Miller and Mohn, 1993; Hart and Gorfine, 1997; Haakana and Huuskonen, 2008).

The size of crayfish population in Keban Dam Lake was calculated to be 28,450 kg according to Leslie regression model (Leslie and Davis, 1939). This figure represents the number of crayfish at minimum fishing size found in Kemaliye, Ağın, Keban and Çemişgezek, which are zones of fishing crayfish for commercial purposes, at the beginning of fishing season (Figure 1). 16,867 kg of this estimated figure were removed from the population of 2012 crayfish fishing season. Taking into consideration that there are no illegal fishing activities conducted outside season, crayfishes smaller than 10 centimeters are not caught and approximately 60% of the population at legal length is caught on a season, we can say that the population is not exploited and is balanced.

There is only one previous study focusing on the size of crayfish population in Keban Dam Lake. The study by Yüksel and Duman (2011) focused on Ağın, Keban and Çemişgezek districts in 2006 and noted that catch per unit effort was approximately 2.9 kg/100 fyke nets/week. The same study estimated the size of population by using mark-recapture method and announced that the stock above the legal fishing size of a fish enforced back then, namely 9 cm and above, was 201,086 kg. This figure is highly more than the stock estimated on our study. The methods used for both studies and minimum legal lengths accepted (9 and 10 cm) are different from each other. Another study focused on the area (Yüksel and Duman, 2012) underlined that the fishes between 9 and 10 cm make up 36% of the catch composition.

According to the conclusion of this study, regression model (removal method) suggested by Leslie and Davis (1939) for estimating the size of population can offer important data for crayfish

Table 1. Weekly catch per unit effort (CPUE) values of Keban Dam Lake 2012 crayfish fishing season

t	C (Catch, kg)	Fishing boat (nos)	f 100 Fyke Net (nos)	CPUE		
				C/f (Y)	SE	K_t (X)
1	2862	28	456	6.28	0.99	0
2	2894	28	456	6.35	0.73	2862
3	2302	28	456	5.05	0.78	5756
4	2199	27	453	4.85	0.70	8058
5	1925	27	453	4.25	0.79	10257
6	1559	27	453	3.44	0.61	12182
7	1460	24	393	3.72	0.63	13741
8	1083	22	363	2.98	0.56	15201
9	583	12	213	2.74	0.51	16284

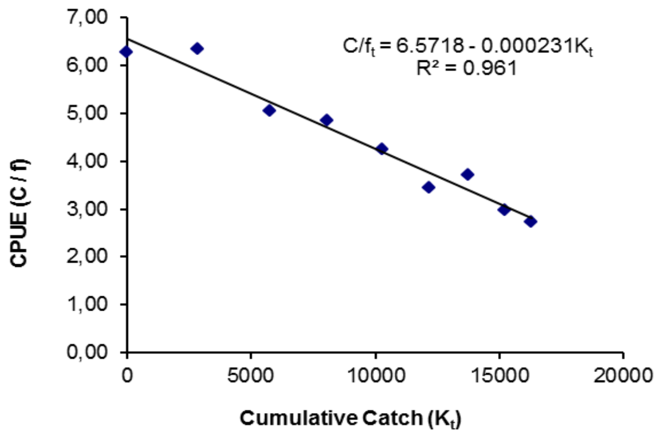

Figure 2. Linear regression by cumulative catch (K_t) and CPUE.

population drastically reduced as a result of each fishing activity.

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