Digest Journal of Nanomaterials and Biostructures Vol. 9, No. 1, January - March 2014, p. 167 - 174

ESTIMATION OF THE POPULATION SIZE OF *CAPOETA UMBLA* (HECKEL, 1843) IN THE LAKE HAZAR (ELAZIG) BY REMOVAL METHOD

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Fish populations in smaller aquatic environments are affected by the fishing pressure at a much faster pace. Often, compensation of this effect either takes a long time or is not possible at all. For the purposes of establishing fishing regulations in these water environments, the removal method is able to provide results quickly and almost accurately. The Lake Hazar, which is the environment of our study, is 8,600 hectares in size, and is a natural lake where *Capoeta umbla* species is caught commercially using gill nets. In this study, stock size of *Capoeta umbla* in the Lake Hazar (Elazig) was estimated using removal method. In addition, the power of fishing and the status of fishing yield in the lake were evaluated. In our research, it was determined that seven commercial fishing boats caught 25,721 kg of fish in the lake in a fishing season. CPUE was calculated as 1.55 kg (kg/day/a gill net). As a result of the regression analysis, the amount of stock in the lake was the estimated to be 37,781 kg (± 14,001 kg). When cumulative catch was formulated as recommended by Ricker (1975), the population size was estimated to be 38,649 kg (± 15,007 kg). As a result of our study, the use of removal method was found to be appropriate for small reservoirs with reduced population density due to strong fishing pressure.

(Received November 14, 2013; Accepted January 24, 2014)

Keywords: Lake Hazar, *Capoeta umbla*, Removal Method, CPUE, Stock Assessment

1. Introduction

Fish populations in reservoirs especially with small surface area are affected by fishing pressure very quickly and if no measure is taken, they drop to a level that it is not possible to get any fishing yield. For this reason, fishing regulations should be planned very well for a sustainable fishing practice. This planning will not only be beneficial for the protection of fish populations but also ensure that the necessary investment is made for fishing. For the fishing regulations to be designed, the fish species in the reservoir and the size of the populations of these species needs to be known. In the transition to modern fishing, besides the tools and equipment used for fishing, the knowledge of the properties of populations is also of great importance [1].

The purpose of fisheries management is to regulate fisheries policy in order to avoid any decrease in productivity (yield) in terms of the products obtained from sources [2]. Fisheries management is regulated to be limiting in the case of overfishing and incentivizing in the case of underfishing [3]. Establishing and implementing a successful fisheries management depends first and foremost on healthy data [4].

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A variety of methods are used by the researchers to control the fish stock and estimate the population size. These methods are selected by taking into account all the features of the aquatic environment where the research study will be conducted and the fish species available in that aquatic environment.

Some researchers compared more than one method in the same aquatic environment and tried to select the best method for the respective environment [5-7].

The Lake Hazar has an altitude of 1,248 m, a surface area of 8,600 hectares, and a depth of 219 m. Six different fish species live in the Lake Hazar. However, the only species of economical value is *Capoeta umbla*. This fish is named as 'lake fish' or 'brook fish' the Lake Hazar and often mentioned as 'siraz' in the literature [8-11].

In this paper, we use a regression model [12] to estimate abundance and the confidence interval of abundance of *Capoeta umbla* population in the Lake Hazar. In this lake, just as is the case in the assumptions of the removal method, population is closed, catchability is constant over the period of removals, and the units of effort are independent. All fish are equally vulnerable to the method of capture. And, the catches removed more than 2% of the population. This model is successfully used in estimating fish populations [13-15].

2. Materials and methods

The study was conducted between September 2008 and August 2009. The amount of catch per day figures were obtained from seven boats fishing in the lake using gill nets in order to obtain the annual amount of catch and the amount of catch per unit effort. In addition, in order to determine the power of fishing, the specifications and quantities of fishing tools used in these fishing boats were determined. The amount of catch per month was calculated by multiplying the amount of catch per day with the number of days of fishing (kg / month). The annual amount of catch in the lake is calculated by summing the amount of catch during the nine months in a year when fishing is allowed (kg / year). The following equations (1, 2 and 3) were used for this purpose [16].

$$W_d = \sum_{i=1}^{n} W_i \quad (1)$$

$$W_m = \sum_{d=1}^{k} W_d \quad (2)$$

$$W_y = \sum_{m=1}^{m} W_m \quad (3)$$

In these equations;
W_d: The amount of catch per day (kg),
W_m: The amount of catch per month (kg),
W_y: The amount of catch per year (kg),
W_i: The amount of catch of a fisherman (kg),
n: The number of fishermen engaged in fishing,
k: The number of days of fishing in one month,
m: The number of months of fishing in a fishing season.
The amount of catch per unit effort (CPUE) for per 100 m gill net is calculated using the following formula [17, 18]:

$$CPUE = \sum (Y/n)N \quad (4)$$

In the formula;
Y: The amount of catch (kg),
n: The length of the gill net used for fishing (100 m),
N: The number of trials.

The regression model [12] was used to estimate the population size of the *Capoeta umbla* in the Lake Hazar. The initial number of fish in a population is denoted by N_0. The number of fish remaining in the closed population at the start of the *t*th removal is the initial population size minus the cumulative catch prior to the *t*th removal, K_{t-1}. Thus,

$$N_t = N_0 - K_{t-1} \tag{5}$$

where K_{t-1} is

$$K_{t-1} = C_1 + C_2 + \ldots + C_{t-1} = \sum_{i=1}^{t-1} C_i \tag{6}$$

where C_i is the catch for the *i*th removal and $t > 0$ and $K_0 = 0$. In addition, assume that catch per unit effort (CPUE) in the *t*th removal event, C_t/f_t, is simply proportional to the extant population at the time of the *t*th removal event, N_t, i.e.,

$$C_t / F_t = qN_t \tag{7}$$

where F_t is the level of effort for the *t*th removal and q is a proportionality constant typically defined as the catchability coefficient. The catchability coefficient represents the fraction of the population that is removed by one unit of fishing effort. The regression model is derived by substituting (5) into (7) for N_t and simplifying,

$$C_t / F_t = q(N_0 - K_{t-1}) \tag{8}$$

$$C_t / F_t = qN_0 - qK_{t-1} \tag{9}$$

The last expression of (9) is in the form of a linear model where C_t/F_t is the response variable, K_{t-1} is the explanatory variable, q is a constant (i.e., the slope), and qN_0 is a constant (i.e., the intercept) because it is the product of two constants. Thus, the negative of the slope of this model is an estimate of the catchability coefficient, q. The estimated initial population size, N_0, is found by dividing the estimated intercept by q. Visually, N_0 is the intercept of the regression line with the x-axis, or in words, the total cumulative catch such that the CPUE is equal to zero [19].

Ricker [15] suggested a modification to (9) such that K_{t-1} is replaced with K_t, where K_t is equal to K_{t-1} plus half of the current catch, C_t, or

$$K_t = K_{t-1} + C_t / 2 \tag{10}$$

Thus, (9) becomes

$$C_t / F_t = qN_0 - qK_t \tag{11}$$

and q, qN_0, and N_0 are estimated with regression methods as with (9). This modification will typically (but not always) result in slightly higher estimates of N_0.

When the formula no (11) is simplified, the population size (N_0) is calculated by the following formula. Where K is the mean cumulative catch (K_t), Y is the mean CPUE (C_t/F_t).

$$N_0 = K + (Y / q) \tag{12}$$

Confidence intervals for q and N_0 can be derived from the regression results. The confidence interval for q is a straightforward calculation of the confidence interval for the slope. However, the confidence interval for N_0 is not straightforward as it is estimated by the ratio of two random variables. However, Krebs [20] provides a formula for computing the standard error of N_0 [19],

$$SE(N_0) = \frac{S_{y/x}}{q}\sqrt{\left(\frac{1}{n} + \frac{(N_0 - K)^2}{(n-1)S_K^2}\right)} \tag{13}$$

$$\%\ 95\ Confidence\ Limits\ =\ N_0 \pm\ 1.96\left[SE(N_0)\right] \tag{14}$$

where S^2_K is the variance of the cumulative catch, and $S_{y/x}$ is the standard deviation about the regression line. Thus, with these formulas, confidence intervals for N_0 are computed in the standard way assuming normal distributions [19].

3. Results

Commercial fishing activities in the Lake Hazar are carried out with seven fishing boats. These boats are of 5-7 m length, made of wooden material and their engine power varies between 9-28 HP. The average number of gill nets per boat is 12 and the length of each gill net varies by the hanging ratio; however they are approximately 100 meters. A large part of these gill nets are of monofilament structure with mesh sizes ranging from 56 to 100 mm. In addition, trammel nets are also used in the lake. In trammel nets, the mesh size of the net ranges between 36-60 mm in the middle whereas the mesh size of the net ranges between 220-360 mm on the edges.

A total of 25,721 kg *Capoeta umbla* were caught in the Lake Hazar during the fishing season when this study was conducted. In the fishing season, the lowest production was observed in February (1,201 kg) whereas the highest production was realized in October (4,577 kg). The amount of catch per day was 129.9 kg on average and the average amount of catch per fishing boat was 18.56 kg (Table 1). The monthly distribution of the average daily amount of catch of a fishing boat (kg / day) is given as a graph in Figure 1.

Table 1: The Lake Hazar Capoeta umbla production data for 2008-2009 fishing season

Month	Production (kg)	The amount of total catch per day (kg)				The amount of catch per fishing boat per day (kg)			
		kg/day	SE	Min.	Max.	kg/day	SE	Min.	Max.
Sep.	4,232	192.4	43.98	158.2	263.2	27.48	9.55	10	45
Oct.	4,577	208.0	43.34	179.2	284.2	29.72	10.42	13	50
Nov.	3,554	161.6	15.67	142.8	179.2	23.08	5.40	15	37
Dec.	3,249	147.7	21.28	130.2	176.4	21.1	4.66	13	30
Jan.	1,793	81.5	6.05	72.8	88.2	11.64	2.12	7	15
Feb.	1,201	54.6	3.79	49.0	57.4	7.8	1.82	5	11
March	2,193	99.7	19.58	75.6	120.4	14.24	4.37	7	25
July	2,187	99.4	8.22	89.6	107.8	14.2	2.88	10	21
Aug.	2,735	124.3	4.57	117.6	130.2	17.76	3.28	13	24
Total	25,721	129.9				18.56			

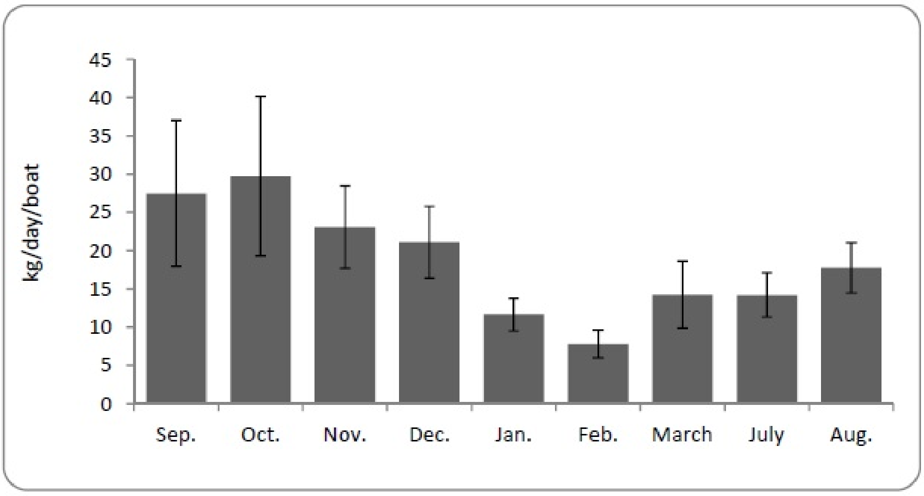

Fig. 1: The distribution of daily production per boat by months

When the daily amount of catch per gill net (100 m) (CPUE) was calculated, the minimum was 0.65 kg, the maximum was 2.48 kg, and the average was 1.55 kg.

Approximate estimation of the population size of *Capoeta umbla* in the Lake Hazar was calculated according to the regression model using the data obtained as a result of the fishing performed by seven fishing boats in the lake in the course of nine months. 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 2. Fishing power data used in the calculations represent the product of the amount of gill nets used by the fishermen, the number of days of fishing, and the number of boats used for fishing. Here, 10 pieces of gill nets were regarded as a set of nets.

Table 2: The data used in the estimation of population size

Month	**Catch**	**Effort**	**CPUE**	**Cum_Cat_1**	**Cum_Cat_2**
t	**Ct**	**Ft**	**Ct/Ft**	**K_{t-1}**	**K_t**
1	4232	18.48	229.00	0	2116.0
2	4577	18.48	247.67	4232	6520.5
3	3554	18.48	192.32	8809	10586.0
4	3249	18.48	175.81	12363	13987.5
5	1793	18.48	97.02	15612	16508.5
6	1201	18.48	64.99	17405	18005.5
7	2193	18.48	118.67	18606	19702.5
8	2187	18.48	118.34	20799	21892.5
9	2735	18.48	148.00	22986	24353.5
Total	25721	166.32	1391.83	120812	133672.5

The estimates obtained from the regression of the catch per unit effort using the Leslie model and their respective statistical analyses are given in Table 3. When K_{t-1} (Cum_Cat_1) is used as the "x" in the regression model, the initial population size of *Capoeta umbla* in the Lake Hazar was estimated to be 37,781 kg. The standard error of the initial population size was calculated as 7,144. Lower confidence limit (95% LCL) and upper confidence limit (95% UCL) were calculated to be 23,779 kg and 51,782 kg, respectively. When K_t (Cum_Cat _2) was used as the "x" in the regression analysis as is proposed by Ricker (1975), the initial population size was estimated to be 38,649 kg. This estimate appears to be slightly higher than the value calculated by the original Leslie regression model. In this calculation, the standard error of the initial population size was 7,656. Lower confidence limit (95% LCL) and upper confidence limit (95% UCL) were calculated to be 23,643 kg and 53,656 kg. Linear regression plots and equations for the cumulative catch 1 (K_{t-1}) and cumulative catch 2 (K_t) are provided in Figure 2 and Figure 3, respectively.

Table 3: Parameters obtained from the regression of catch per unit effort (CPUE)

Cum. Catch	Term	Estimate	95% LCI	95% UCI	Std. Err.	t ratio	Sig.
	Intercept	239.88	197.36	282.40	27.26	8.80	0.000
Cum_Cat_1	q	0.006349	0.003229	0.009469	0.002	-3.56	0.009
	N_0	37781	23779	51782	7144		
	Intercept	251.17	199.88	302.46	32.88	7.64	0.000
Cum_Cat_2	q	0.006499	0.003379	0.009619	0.002	-3.24	0.014
	N_0	38649	23643	53656	7656		

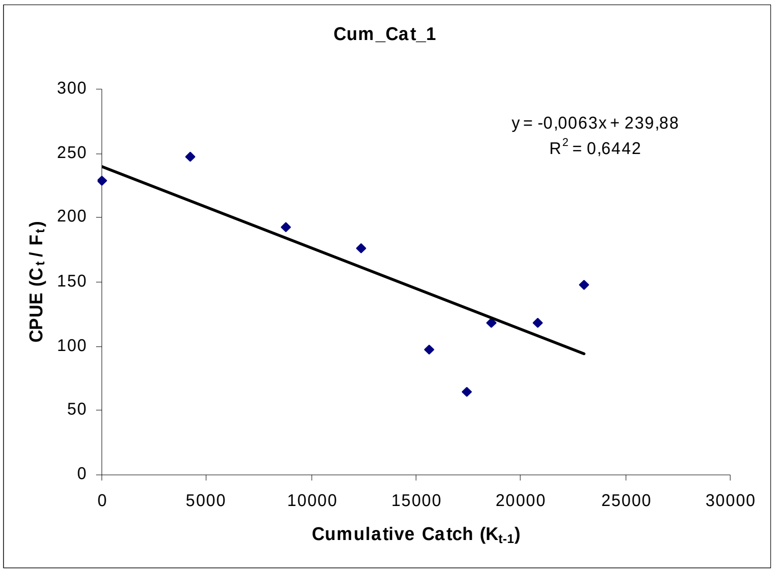

Fig.2. Linear regression by cumulative catch (K_{t-1}) and CPUE

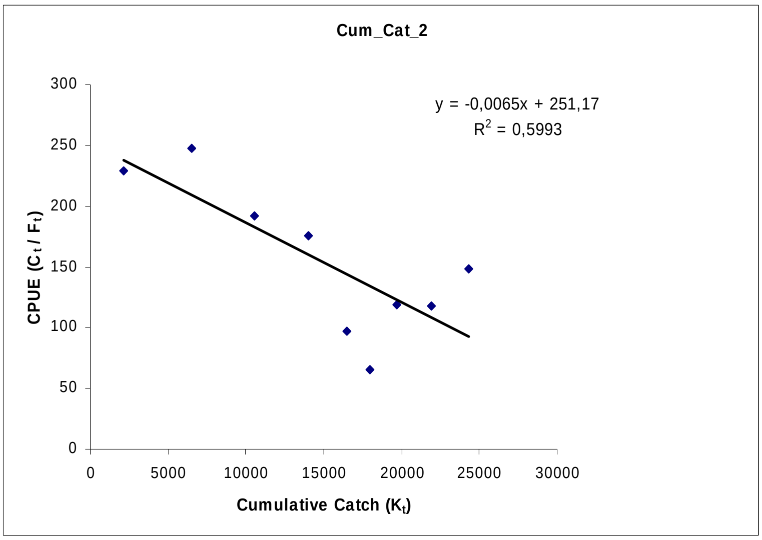

Fig. 3. Linear regression by cumulative catch (K_t) and CPUE

4. Discussion

The Lake Hazar has great potential in terms of fishing. Although there are six fish species in the lake [11], only *Capoeta umbla* among these is regarded as having economical value. According to the findings of this study, fish stock per hectare, which is determined using two different cumulative catch data, ranges from 4.39 to 4.49 kg.

In a study conducted in 2001 [1], the number of boats engaged in fishing in the lake was reported to be 13. In the same study, it is reported that the length of fishing boats ranged from 4.5 m to 5.5 m; engine powers ranged between 6-14 HP, and 23,408 kg of fish were caught with 124 gill nets which belonged to the 13 fishing boats. In that case, it is understood that the CPUE was 0.83 kg 10 years ago. Both the lengths of the boats and engine powers have increased today. However, due to the low fishing efficiency and the narrow reservoir area, the numbers of fishing boats have decreased to seven within the last 10 years. Again, there is a decrease in the number of gill nets used (84) in comparison to 10 years ago. Despite this difference in the fishing power, there was no decrease in the amount of production. The amount of catch per boat per day (18.56 kg) was found considerably higher than the previous one. Accordingly, the amount of catch per unit effort in our findings (1.55 kg) is approximately two times higher than the findings of the aforementioned study. This finding is considered a change in accordance with the principle of obtaining the yield at the minimum cost. However the decline in fishing power was not due to the fishing regulations of the authorities but because of the decrease in profitability and consequently was a result of cessation of fishing. Consideration of the figures presented in this study in the fishing regulations for the lake is suggested to be important in terms of sustainable fishing.

5. Conclusions

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 [6, 13, 21-25]. As a result of this study, we observed that the model produces good results when used in an appropriate environment and by taking into account its assumptions. We can suggest the use of this model for small reservoirs which have declining population due to strong fishing pressure.

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