

Full Length Research Paper

Estimating the population size of *Astacus leptodactylus* (Decapoda: Astacidae) by mark-recapture technique in Eğirdir lake, Turkey

Yildiz Bolat^{1*}, Yavuz Mazlum², Aydin Demirci² and Habil Uğur Koca¹

¹Department of Fishing and Fish Processing Technology, Faculty of Fisheries, University of Süleyman Demirel, 32500 Eğirdir, Isparta, Turkey.

²Faculty of Fisheries, Mustafa Kemal University, TR-31200 Iskenderun-Hatay, Turkey.

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The mark-recapture technique for closed populations was employed to estimate the population size and density of *Astacus leptodactylus* during August and September, 2005 by using minnow traps of 34 mm mesh size in Eğirdir Lake. A total of 600 minnow traps were set randomly along the shoreline at approximately 3, 5 and 7 m depth. The nets were set in the late afternoon to each study depths, and were hauled the next day or after two days. The research was performed two times each month. In August, 1956 adult crayfish and in September, 2756 adult crayfish were marked by cauterization of the carapace. The recapture rates were found to be 3.5% in August and 2.3% in September, respectively. A total of 200 crayfish were randomly selected, 74 females and 126 males. The sex ratio was 1:1.7. Moreover, length and weight data gotten from 200 untagged crayfish showed that females and males differed significantly in their weight, but no significant difference was evident in the carapace length. From the mark-recapture experiment, it was estimated that catchable population size ranged between 32590 and 73503 individuals (with carapace length above 45 mm). Estimated density ranged between 0.54 and 1.2 individuals per m². Recapture rates did not differ statistically among occasions. Despite the moderate and fluctuated growth in the crayfish population, catchable population should be estimated for each region in the lake by using the estimation methods.

Keywords: *Astacus leptodactylus*, density, Eğirdir Lake, mark-recapture, narrow clawed crayfish, petersen methods, population size, Turkey.

INTRODUCTION

Astacus leptodactylus is a native species that has become widely introduced to many countries, such as Poland, Italy, Germany, England, Spain and France and it is one of the most valued species for aquaculture (Harlioğlu, 2008). Under natural circumstances, *A. leptodactylus* has a widespread distribution in lakes, ponds and rivers in many parts of Turkey (Harlioğlu and Harlioğlu, 2006). The lake Eğirdir is the main crayfish source and also supports Turkey's natural crayfish yield. Approximately, 2000 tonnes of *A. leptodactylus* were

harvested annually from Eğirdir Lake between 1976 and 1984 (Bolat, 2001). Until 1984, freshwater crayfish played an important role as a life high quality export product, but after 1986, crayfish production declined dramatically in most lakes and dam reservoirs from totally 5000 to 200 tonnes. Hence, *A. leptodactylus* harvesting was forbidden between 1987 and 1999 in the lake because of severe mortalities due to the crayfish 'plague' *Aphanomyces astaci* (Schikora, 1903) infection, pollution, overharvesting and agricultural irrigation (Baran and Soylu, 1989; Bolat, 2001; Harlioğlu, 2004). Although, the 'plague' is still observed in some lakes (Eğirdir, Işikli and Beyşehir) in Turkey, there has been an increase in the amount of *A. leptodactylus* harvested (Diler et al., 1999; Diler and Bolat, 2001).

According to the Turkish Fishery Regulations, minimum landing size for *A. leptodactylus* was 90 mm of the total

*Corresponding author. E-mail: yldzbolat@gmail.com or ybolat@sdu.edu.tr. Tel: +90 2463133447. Fax: +90 2463133452.

length (TL) until 2006. Harvesting season opens on June 15th onward and closes on the 1st of November in the lake. Crayfish has been heavily exploited for nine years in Eğirdir Lake. The harvested yield (tonnes) were 128 in 1999, 358 in 2000, 797 in 2001, 274 in 2002, 581 in 2003, 397 in 2004, 114 in 2005, 34 in 2006 and 14 in 2007. Crayfish fishing was allowed again in 1999 due to an increase in the abundance of the population and political reasons. In this period, crayfish harvesting dropped from 797 to 14 tonnes. No routine programme was initiated to monitor the population dynamics of *A. leptodactylus* in Eğirdir; moreover, the regulations of management were not sufficient.

The estimation of population size provides an important information in ecological field studies, especially when species face the risk of extinction. Description of several field methods for estimating the size open closed populations and which require that mark-recapture techniques be employed are available in literature (Krebs, 1989). Mark-recapture studies have been proven useful for obtaining information on the migration, growth, population size and mortality rates of many aquatic animal species. This estimation method requires a methodology designed to assess the population size within a known area. It can be carried out either in terms of relative abundance using catch per unit effort data, absolute abundance using census methods or mark-recapture techniques (Pollock et al., 1990). Mark-recapture experiments assume an equal catchability of both marked and unmarked individuals (Ricker, 1975), but several factors can affect this assumption. Traps are size and sex-selective (Qvenild and Skurdal, 1989), and may also be selective because of the moulting, reproductive status and health condition of the animals (Abrahamsson, 1983; Skurdal et al., 1988, 1989). Sampling, handling and marking may also cause stress in the organisms which reduces the trapability of individuals once they are marked (Abrahamsson, 1983).

This paper presents the estimated population size and density of *A. leptodactylus* in Eğirdir Lake in two different occasions by the mark-recapture method. The density of mature individuals obtained for each estimate was employed to project the population size of *A. leptodactylus*. It also allowed us to compare variations in population size and density in future occasions.

MATERIALS AND METHODS

The surface area of Eğirdir Lake is 479 km² and the average depth is 8.5 m (Altinkale, 2001). The lake is inhabited by 13 species of fish, including common carp, *Cyprinus carpio* (L. 1758) and pike perch *Sander lucioperca* (L. 1758), which are only important predator of crayfish (Bolat, 2001). In addition, *Potamogeton* sp., *Myriophyllum* sp., *Ranunculus* sp., *Sagittaria* sp., *Phragmites* sp. and *Chara* sp. are the most common aquatic macrophytes (Kesici, 1997) providing food and shelter for crayfish in the lake.

A total of 600 minnow traps with 34 mm mesh size (Figure 1) were set randomly along the shoreline at approximately 3, 5 and 7 m depth, in two sampling sessions; August and September, 2005,

respectively (Table 1). The nets were set in the afternoon, and hauled in the morning after three days, because *A. leptodactylus* is nocturnal and often hides in shelters during the day (Bolat, 2001). The nets were baited with Prussian carp, *Carassius gibelio* (Bloch, 1782). The fish were, as a common practice, frozen and thawed before been used as bait (Taugbol et al., 1997). After collecting all nets, they were returned to the same positions. The study area was approximately 1000 m of shoreline on the eastern side of the lake (Figure 2).

The Lincoln-Petersen method also known as the Lincoln index was used for estimating the catchable population size in the study area. Estimations of catchable population size were performed in four different occasions: two in August and two in September 2005. The nets had never been used in other lakes, because of the risk of crayfish 'plague' transmission. The carapace length (CL) and total weight (TW) of randomly sampled (100 specimens in August 31, 100 specimens in September 28) and sexed 200 specimens were measured with Vernier caliper to the nearest 0.1 mm, while weight was measured to the nearest 0.01 g.

A total of 7390 specimens were sampled. Crayfish with CL above 45 mm (n = 4712) were tagged by cauterization of carapax on board and released. The crayfish were tagged on the right side of carapax in August and on the left side in September. They were observed for a few minutes in a tray filled with water, in order to check for the general health condition. The crayfish were kept in large boxes with covers to avoid sunlight until they were marked and released into the lake. The marking operation lasted for 2 to 3 h and the marked crayfish were released within the same area in which they were initially captured.

The Chapman (1951) modification of the Lincoln-Peterson formula was applied to estimate the population size (e.g. the number of crayfish ≥ 45 mm CL) within the study area:

$$N = [(m+1) (c+1) / (r+1)] - 1$$

Where, N is an unbiased estimator of population size at the time of marking, m is the number of marked crayfish, c is the catch taken for census and r is the number of recaptured marked crayfish in the catch. The Petersen formula is based on the following assumptions: i) the marked crayfish suffer the same mortality as the unmarked; ii) they are as vulnerable to trapping as the unmarked ones; iii) they do not lose their marks; iv) they become randomly mixed with the unmarked; v) all marks are recognized and reported; and vi) there are no births or immigration and no deaths or emigration, or neither (Ricker, 1975; Byrne et al., 1999). After been returned to the same depths, it was ensured that they did not leave their habitats and sheltered in two occasions. Therefore population was assumed 'closed'. Chapman showed that the variance of N can be estimated as:

$$\text{var}(N) = [(m+1) (c+1) (m-r) (c-r)] / [(r+1)^2 (r+2)]$$

An approximate 95% CI (normality for N is assumed) can be estimated according to Youngs and Robson (1978) as:

$$N \pm 1.96 * [\text{var}(N)]^{0.5}$$

Density was found by the formula: D = N/A (where N is the population size in numbers and A, is the area occupied by the crayfish population) (Seber, 1973).

Statistical analysis

Statistical analyses were performed using SPSS 16.0 for Windows package. Differences between recapture rates were analyzed by chi-square and differences in the population sizes between

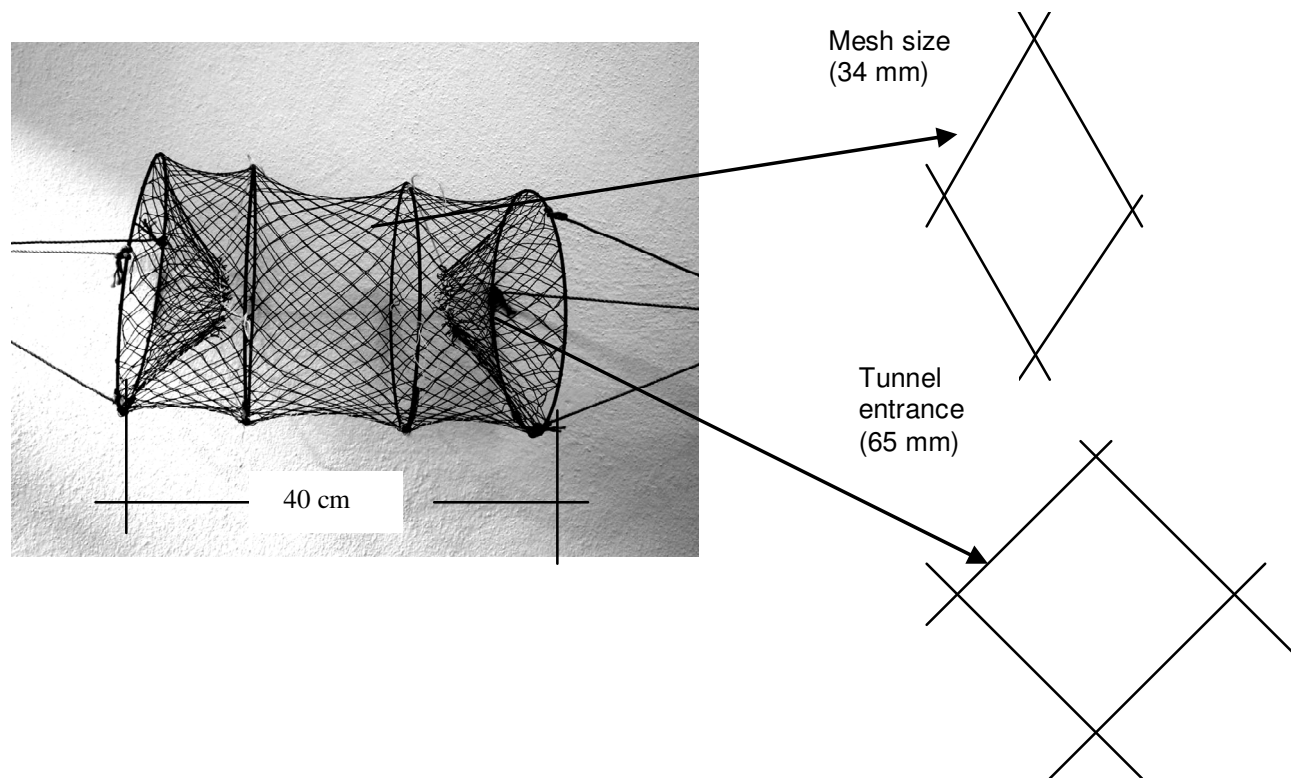


Figure 1. Funnel trap designed and used to capture crayfish.

Table 1. The mean length and weight of the legal sized crayfish.

Sex	Number	Carapace length (CL) ± SE	Body weight (WB) ± SE
Male	126	66.28 ± 0.162 ^a (45-86)	78.04 ± 1.819 ^a (24.7-172.5)
Female	74	63.25 ± 1.52 ^a (45-81)	61.52 ± 1.868 ^b (28-114.2)
Total	200	65.82 ± 0.416 (45-86)	75.76 ± 0.846 (24.7-172.5)

The different letters in the same column are statistically difference (p<0.05).

occasions were analyzed by one-way analysis of variance (ANOVA). The least significant difference (LSD) test was applied to determine the differences in average weight and length between males and females. Statistical analyses were considered significant at the p<0.05 level.

RESULTS

Weight and length measurements

Weight and length data were based on a sample of 200 specimens (74 females and 126 males at a ratio of 1:1.7) of *A. leptodactylus*. Statistical difference between the sexes was significant ($\chi^2 = 13.52$, $df = 1$, $p < 0.05$). The mean (\pm standard error) CL was 66.28 mm (± 0.162) (range: 45 to 86 mm) for males and 63.25 mm (± 1.52) (range: 45 to 81 mm) for females. The mean weight values were found to range between 24.7 and 172.5 g and the mean weight was measured at 78.04 g for males

and 61.52 g for females (Table 1). While difference between the mean length of males and females was found to be insignificant ($p > 0.05$), male and female weight were significantly different ($p < 0.05$) and adult males predominated in all the sampling events.

Mark-recapture experiment

In 27 and 31 August, 1956 crayfish were marked, 69 were recaptured, and 2756 crayfish were marked and 63 were recaptured in 24 and 28, September 2005. The difference between the four population size estimations were found to be statistically insignificant ($\chi^2 = 2.83$, $df = 3$, $p > 0.05$). Recapture rates were statistically not different ($\chi^2 = 0.335$, $df = 3$, $p > 0.05$) between August and September. Catchable population size and density was estimated at a range of 32590 and 73503 individuals of CL ≥ 45 mm and 0.54 to 1.22 individuals per m²,

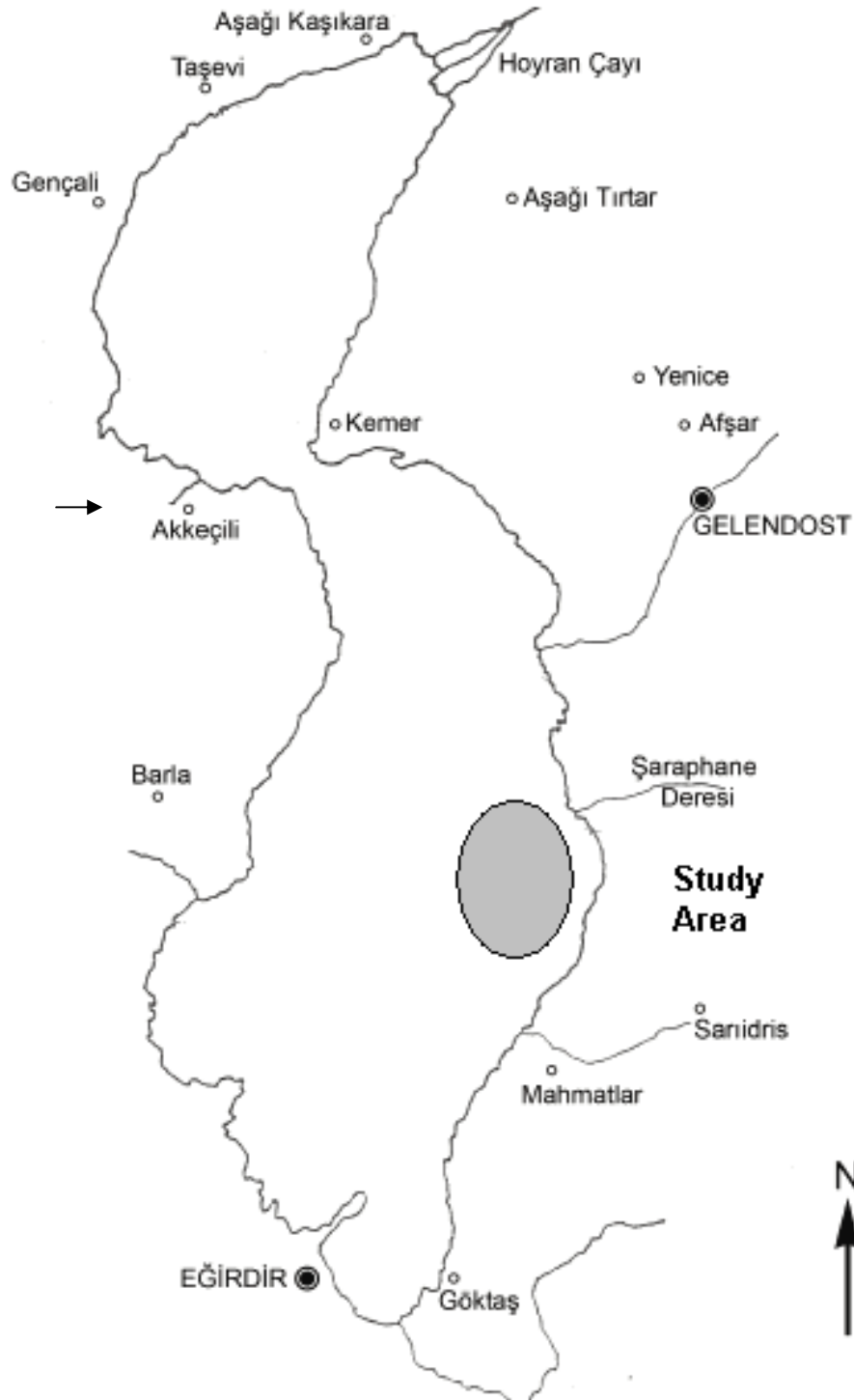


Figure 2. The study area in Egridir Lake.

respectively (Table 2). The 95% CI ranged from 29.6 to 35.6% of the estimated population size. The population size for September 28 was significantly different from both August sampling dates ($p < 0.05$). The recovery period was the same in all the occasions. Therefore, it may not have influence on the estimates in this study.

DISCUSSION

This study showed that the mark-recapture technique can provide accurate data on estimating population sizes of *A. leptodactylus*. Marking by clipping the telsons and uropods and by cauterization of the carapax are easy and

Table 2. Population estimates of narrow clawed crayfish, *A. leptodactylus*, on the eastern side of Lake Eğirdir.

Date	T	n	m	Recapture rate (m/T)	N (\pm 95% CL)	Density
August 27	896	1089	29	3.2	32590 \pm 11318 ^b (21272-43908)	0.54
August 31	1089	1432	40	3.6	38096 \pm 11285 ^b (26811-49381)	0.63
September 24	1171	1620	35	2.9	52772 \pm 16795 ^{ab} (35977-69567)	0.88
September 28	1620	1314	28	1.7	73503 \pm 26218 ^a (47285-99721)	1.22

Values in the same column with different superscripts are significantly different ($P \leq 0.05$). T = marked crayfish; n = total catch; m = number of marked crayfish in the catch; N = population number with 95% CL; density = number of crayfish ≥ 45 mm carapax length/m².

rapid methods (Abrahamsson, 1965). Two persons can easily measure and mark 100 crayfish per hour. The marked individuals are easily recognizable and the marks are not lost until the crayfish have molted more than once (Skurdal et al., 1992). When the crayfish are released, they are easily distributed within the study area. Males and females are known to have different trapability (Abrahamsson, 1983) which mainly varies according to the season and sex (Qvenild and Skurdal, 1989). Molted crayfish and egg-and fry-bearing females are rarely caught in baited traps due to the fact that they cannot move out to feed from their shelters.

Mark-recapture experiments in late summer-early autumn (August and September) did not show any statistical difference among the recapture rates. The significant increase in population size was detected in autumn due to the approach of mating in the season. The crayfish were more active and the catchability increased in this breeding period. Out of the 4712 crayfish marked, 2.8% were caught collectively in two months. This percentage was presumably lower when compared to other studies. Another important assumption of the use of mark-recapture methods repeatedly found is, crayfish movements in habitats: individual crayfish occupy a general area for days up to weeks before moving. Flint and Goldman (1977) and Byron and Wilson (2001) observed that *Pacifastacus leniusculus* (Dana, 1852) and *Orconectes rusticus* (Girard, 1852), respectively, stayed within <60 m of their original sites for several days for up to four weeks. In comparison, the shoreline length of our sampling sections ranged from 3 to 7 m.

Crayfish fishing has been performed in Turkey since 1970. However, the legal management regulations for crayfish are not sufficient in Turkey. The initial experiments on mark-recapture techniques were carried out in Lake Dikilitaş (Ankara) (Köksal et al., 2003) and in Hoyran Region of Lake Eğirdir (Isparta) (Bolat, 2004). Recapture rates of marked crayfish in these experiments (2.1 to 2.7%) were lower than those (2.9 to 9.03%) reported by Skurdal et al. (1992), Köksal et al. (2003) and Bolat (2004). In a study calculating the abundance of crayfish with Petersen (1896) mark-recapture method for *P. leniusculus* and *O. limosus*, recapture rates were determined at 15.8% for signal crayfish and 16.1% for spiny-cheek crayfish, and catchable populations were calculated as 2094 and 127 specimens ha⁻¹, respectively

(Krzywosz et al., 2006). Maguire et al. (2004) estimated the population size of *Astacus astacus* (L., 1758) using different mark-recapture methods (Jolly-Seber, Schnabel and Schumacher and Eschmeyer) in 2000 and 2002. Pilotto et al. (2008) estimated the density at 16.7 (\pm 7.3) of *Orconectes limosus* m⁻² by the multiple mark-recapture method.

Estimated density during this experiment ranged between 0.54 and 1.22 individual (of ≥ 45 mm CL) per m². Moreover, estimated density was found to be similar with that of Köksal et al. (2003), Moriarity (1973) and Skurdal et al. (1992). In other mark-recapture experiments on *A. astacus*, the density of adults varied between 0.13 and 1.65 specimens per m² with the highest densities in the rivers and shallow ponds (Cukerzis 1975; Niemi 1977). The 95% CI ranged from 29.6 to 35.6% of the estimated population size. The confidence interval was proportionally similar in both occasions in August and September of the year, 2005.

This study was conducted in a selected area having 60,000 m² and our results indicated that *A. leptodactylus* population was stable. The trapped crayfish demonstrated no clinical signs of crayfish 'plaque' or visible external parasites and were in a healthy condition. Population size estimations indicated that the population may be growing. The knowledge of population size is crucial for planning of commercial fishing, but there is a need for better fisheries management strategies. The following is recommended:

1. Population should be monitored continuously,
2. Catchin effort should be restricted,
3. Catching quota should be applied,
4. Harvest should be moved to land and only special places,
5. Protection zones should be identified for crayfish in the lake, and
6. Crayfish traps should be more selective.

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