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ABUNDANCE OF NARROW-CLAWED CRAYFISHES (*Astacus leptodactylus* Eschscholtz, 1823) AND ITS TRENDS IN LAKE SEVAN, ARMENIA

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Abstract:

The narrow-clawed crayfish (*Astacus leptodactylus* Eschscholtz, 1823) is an indigenous species in Armenia. In 1980s it was occasionally introduced in Lake Sevan where its population started to grow. There is a large scale fishery of the crayfish in the Lake, as its demand remains high. Industrial stock of crayfishes at the Lake monitored annually, shows statistically significant decline in the 2004-2011 period. This decline can be described by logarithmic model $y = -577.5\ln(x) + 2158$, $F = 50.27$, $P<0.001$. The catch rate of crayfish net-boxes also shows logarithmic decline $F = 9.27$, $P<0.05$ in the 2004-2011 period. Since the net boxes are designed to catch the larger size crayfishes only, the decline indicates a decrease of average size among crayfish population. The female fertility does not show statistically significant correlation with the industrial stock of crayfish. It does, however, show negative correlation with the catch rate of the net boxes: $r_{Pearson} = -0.686$, $P<0.05$; $\rho_{Spearman} = -0.647$, $P<0.05$. The correlation can be explained as the big animals are actively removed through harvesting, while smaller animals are not captured; meanwhile the remaining smaller animals produce fewer eggs. Decline of crayfish stock cannot be explained by diseases and invasive species, but can be explained by overharvesting. Continuation of harvesting aimed at supplying the existing demand might result to population decline of more than 70% during next 17 years.

Keywords: Narrow-clawed crayfish, *Astacus leptodactylus*, Abundance, Lake Sevan, Armenia

Introduction

The narrow-clawed crayfish (*Astacus leptodactylus* Eschscholtz, 1823) is an indigenous species in Armenia that initially inhabited freshwater habitats of Ararat Plain. Unlike neighboring Turkey that hosts two freshwater crayfishes (Güner and Harlıoğlu 2009, Harlıoğlu and Güner 2007), Armenia hosts only one species. In 1980s it was occasionally introduced into Lake Sevan, and fairly soon its population and distribution throughout the Lake started to grow. The narrow-clawed crayfish is actively consumed in the internal market of Armenia (e.g. over 300 tons have been sold through various channels in internal market in 2011) and starting in the late 1990's they began to be exported from Armenia. The export volumes increased during the twelve year period, 2000-2011 from 20 tons per year to 1120 tons per year (Statistical yearbook of Armenia 2008, 2012). During this period the main exported crayfishes stock came from Lake Sevan while a much smaller portion was supplied by the aquatic habitats of Ararat Plain and other water reservoirs in the country. Meanwhile the data collected by N. Badalyan (2012), in the period of 2004-2011 suggest decrease of the industrial stock of narrow-clawed crayfishes in Lake Sevan. In comparison to 2004, when the industrial stock was estimated at 1800 tons, they have decreased by 52% in 2011 to about 860 tons. At current, there is reason to assume that in the mid-term the situation with Sevan trout might be repeated, which means that the population of narrow-clawed crayfish may decline to a level making self-reproduction nearly impossible.

At the same time, dozens of studies conducted on various crayfish species show that they are critically essential component in lake ecosystems. Being mainly polytrophic organisms, crayfishes are key consumers and transformers of energy between various components of ecosystems, as they utilize representatives of all trophic levels (Dorn and Wojdak 2004, Momot et al. 1978, Momot 1995, Nyström et al., 1996). Crayfishes can be an essential element in lakes with low productivity of phytoplankton, since in these lakes the detritus and the submerged vegetation (consumed by crayfishes) are the main source of energy. When functioning as a main predator of benthos animals, crayfishes are supporting stability of a wide range of plant-animal communities (Momot et al. 1978, Momot 1995). Crayfishes are also important regulators of biogens, especially phosphorus transferring it from macrophytes to phytoplankton (Kholodkevich et al. 2005), and thus having influence on the level of eutrophication. This is true also for the narrow-clawed crayfish, which had rapidly occupied the ecological niche vacated by the Sevan khramulya (*Varicorhinus capoeta sevangi* Filippi, 1865) – another detritivore, abundance of which has declined due to overfishing (Gabrielyan 1987).

The population of narrow-clawed crayfishes at Lake Sevan was studied by number of authors. The studies have been dedicated on study of spatial distribution, age and sex structure of the population, reproduction, and ecological peculiarities of the species (Badalyan 2011, 2012a, 2012b, Gabrielyan and Ghukasyan 2007, Ghukasyan et al. 2006, 2007, 2008, 2010, 2011, Hovhannisyan 1998, Hovhannisyan and Ghukasyan 1996, Reports of SCZH of NAS RA, 2010, 2011).

Taking above mentioned into account there is a necessity to identify the population trends of the narrow-clawed crayfish in the Lake. This will allow for modeling of the unfavorable scenario of population decline, which will enable taking of timely measures to mitigate critical changes of the population. Thus the current article is focused on analyzing the collected data, which is aimed at determination of existing trends and their relations to various influencing factors and modeling future trends in Lake Sevan's population of narrow-clawed crayfish.

Materials and Methods

Lake Sevan is a largest freshwater Lake Sevan of Armenia that has a surface area of about 1,250 km², is situated on 1,896 meters above sea level, which makes it one of the largest freshwater high-mountain lakes of Eurasia; also it is the single biggest source of water in Armenia (see country map in Figure 1).

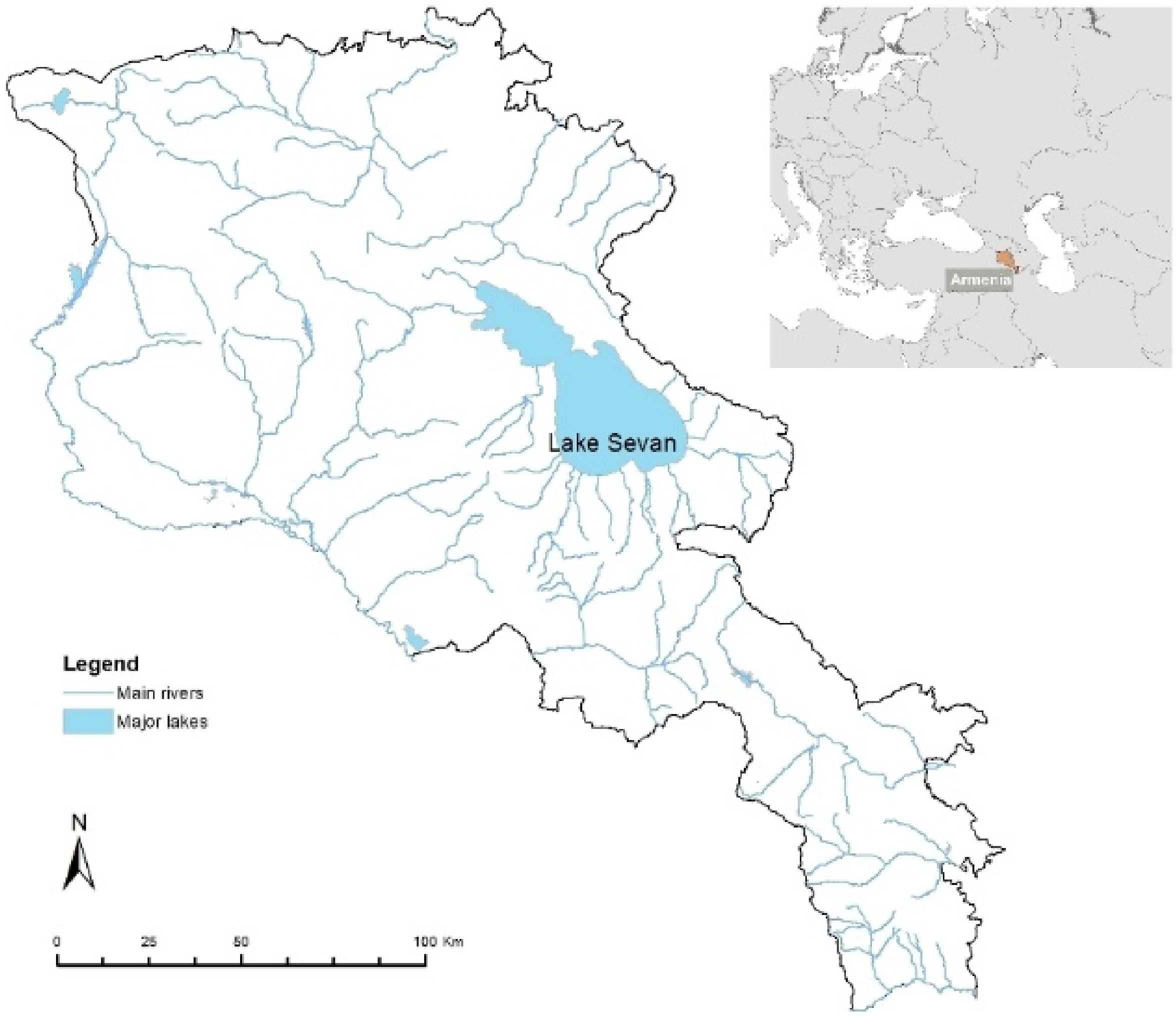

Figure 1. Position of Lake Sevan in Armenia

As a material for the current article we have used statistical data published in official annual Reports of Scientific Center for Zoology and Hydrobiology (SCZH). The data for these reports have been collected in frames of annual monitoring implemented by SCZH at 33 sites covering the entire shore of the Lake with average distance between the sites 5.73±2.06 km. The crayfishes have been sampled using capturing method (Budnikov Tretyakov1952). The method is based on sampling of crayfishes by standard traps with cell size 21x21 mm. The method provides data on relative abundance of crayfishes. In total there are more than 17,000 crayfishes sampled and the initial data on industrial stock of crayfishes (Kireev 1933), catch rate of the net-boxes and crayfish female fertility was collected and reported (Reports of Institute of Hydroecology and Ichthyology of SCZH 2010, 2011). The data of industrial stock is measured as estimate of tons of crayfishes per annum; the data on catch rate of the net-boxes is measured as average number of captured individuals per net-box; the data on female fertility is measured as average number of eggs per female. In addition interviews of five fishery companies operating at Lake Sevan have been conducted. The main aim of the interviews was to identify cases of crayfish mortality due to major diseases listed for the species (Harlıoğlu 2004, Longshaw 2011); for implementation of interviews no formal questionnaires have been developed.

The processing of the collected data was implemented in two stages: (1) the normality of distribution of collected data has been tested and (2) subsequently the appropriate methods of correlation or regression analysis have been selected. Taking small sample sizes into account we have been using Shapiro-Wilk test for testing the normality. When the response data was normally distributed we have been selecting linear regression, otherwise the non-linear models have been applied. To characterize the non-linear models we have been using F-statistics and its probability to determine the significance of the model (Pagano & Gauvreau 1993, Wayne 2009). During data processing we have been using Microsoft Excel 2007 and SPSS 11.0 for Windows.

Results and Discussion

Analysis of the annual data on estimated industrial stock shows that the variable of industrial stock did not show normal distribution and the logarithmic regression method was selected as the one that has higher probability of F-statistics. Application of logarithmic regression model for the estimated industrial stock shows that crayfish population shows statistically significant tendency of consistent decrease, $F = 50.27$, $P<0.001$ (see Figure 2). The model is described by equation $y = -577.5\ln(x) + 2158$, where y is industrial stock, and x is the year.

The next step in our analysis was to understand some trends in catch rate of the net-boxes. The distribution of the variable is out of normal as well and the logarithmic method has also been selected. The analysis allows determining of a declining tendency of catch rate of the net-boxes, $F = 9.27$, $P<0.05$ (see Figure 3).

The latest might be indicating population decline or decrease of average size of crayfishes; because the size of the net-box cell made especially to let the smaller crayfishes to escape the net-box. Decrease of crayfishes' size can mean changes in age structure of population and decrease of number of old big crayfishes.

It is worth to mention that the catch rate of the net-boxes has a correlation with industrial stock at significance level of $P < 0.01$: $r_{Pearson} = 0.809$, $P<0.01$; $\rho_{Spearman} = 0.814$, $P<0.01$, which is an additional confirmation of the observed tendencies.

Another pattern is observed during analysis of the average fertility of females (see Figure 4), which was growing during 2004-2007 but then starts declining. Such dynamics can have a possible explanation that the fertility has late response to overharvesting; thus while the observed increase might be a segment of a long-term tendency of previous years, the decrease that follows might be an indication of influence of overharvesting. To understand the true characteristics of the tendency a longer term investigations are required.

When comparing the catch rate of the net-boxes versus female fertility the negative correlation trend is determined at significance level of $P < 0.05$: $r_{Pearson} = -0.686$, $P<0.05$; $\rho_{Spearman} = -0.647$, $P<0.05$. The fact of the relatively low significance level of the correlation is probably a result of relatively small sample size (n = 8). Such tendency can be explained by overharvesting. Due to consistent harvesting of large amount of crayfishes with size of 12 cm and more, the average size of crayfishes is decreasing. It has the following consequences: (1) smaller animals are not captured because they are able to escape the net-boxes, but the big animals are removed; (2) the proportion of smaller animals in population is increasing and those smaller females produce fewer eggs. Continuation of the surveys will allow obtaining better statistical results.

The cases when decline of narrow-clawed crayfish's population occur are well known in Turkey, Hungary, Russia, and Serbia (Aydin et al. 2012, Dartay and Atessahin 2013, Fedotov et al. 1998, Harlioğlu and Harlioğlu 2004, 2009, Puky et al. 2005, Souty-Grosset et al. 2006). The investigations suggest several reasons of rapid and dramatic decline of narrow-clawed crayfishes. In Turkey the main driving force of the population decline is still unclear and while some authors refer to combination of overharvesting, crayfish plague, and pollution with main stress to overharvesting (Harlioğlu and Harlioğlu 2004, 2009), the others consider the crayfish plague as the main factor among others, that causes strong decline (Kokko et al. 2012, Svoboda et al. 2012). In Hungary the species has been eliminated in Lake Balaton and later in the lower stretch of the inflowing River Zala due to introduction of the European eel (*Anguilla anguilla*), and in the Hungarian part of River Danube due to spread of introduced crayfish species *Orconectes limosus* (Puky et al. 2005). In Russia water pollution was mentioned as the main cause for declines of local population of the lower part of River Don (Fedotov et al. 1998, Souty-Grosset et al. 2006). In Serbia the species declined in some regions due to introduction of *Orconectes limosus* (Holdich et al. 2009). It is also confirmed by other investigations that the invasive species such as *Pacifastacus leniusculus* and the *Orconectes limosus* can be major threats to this species (Lózan 2000). According to our data the epidemics of crayfish plague, as well as other diseases, well known in other parts of narrow-clawed crayfish's distribution range have not been recorded. In accordance to the information of State Environmental Effect Monitoring Center the pollution level of the Lake by chemicals was not significantly changed. It let us to conclude that the overharvesting might be one of the main reasons of declining of narrow-clawed crayfishes in Armenia. The fact of increase of crayfish harvesting is conditioned by the good demand for the product in the world (e.g. only in Europe the crayfish demand can reach 10,000 tons per annum), which is proven by the increasing export of crayfishes from Armenia (see Figure 5) to the countries of European Union, North America, Post Soviet countries, etc. (Statistical yearbook of Armenia 2012).

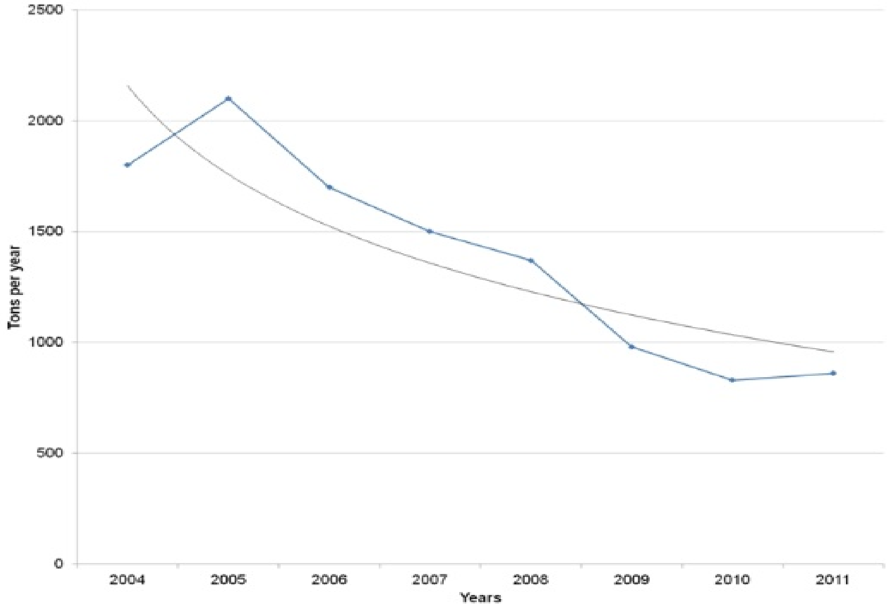

Figure 2. Dynamics of industrial stock of narrow-clawed crayfishes in Lake Sevan during the period 2004-2011

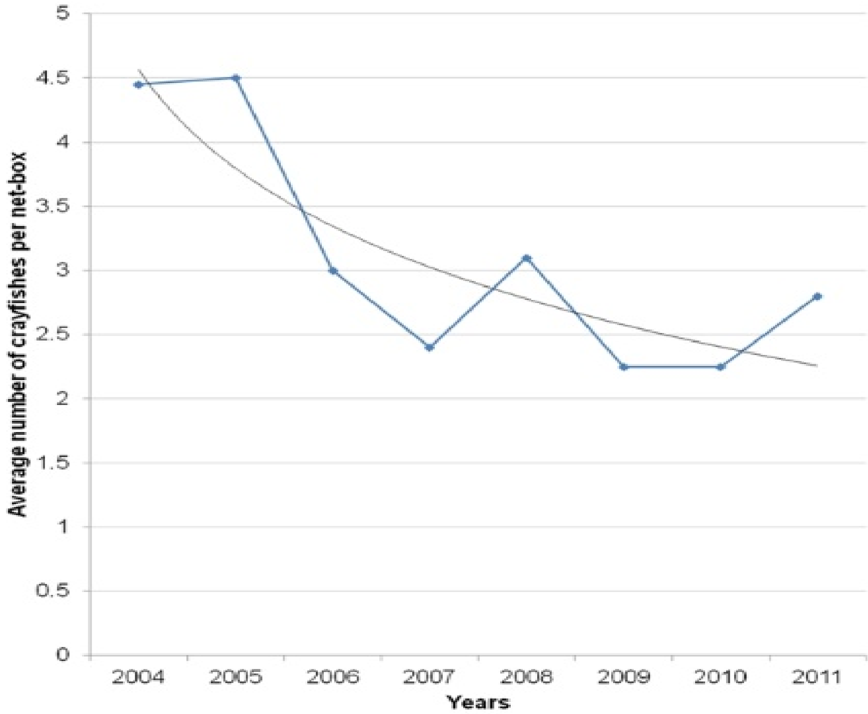

Figure 3. Dynamics of catch-rate of net-boxes in Lake Sevan during the period 2004-2011

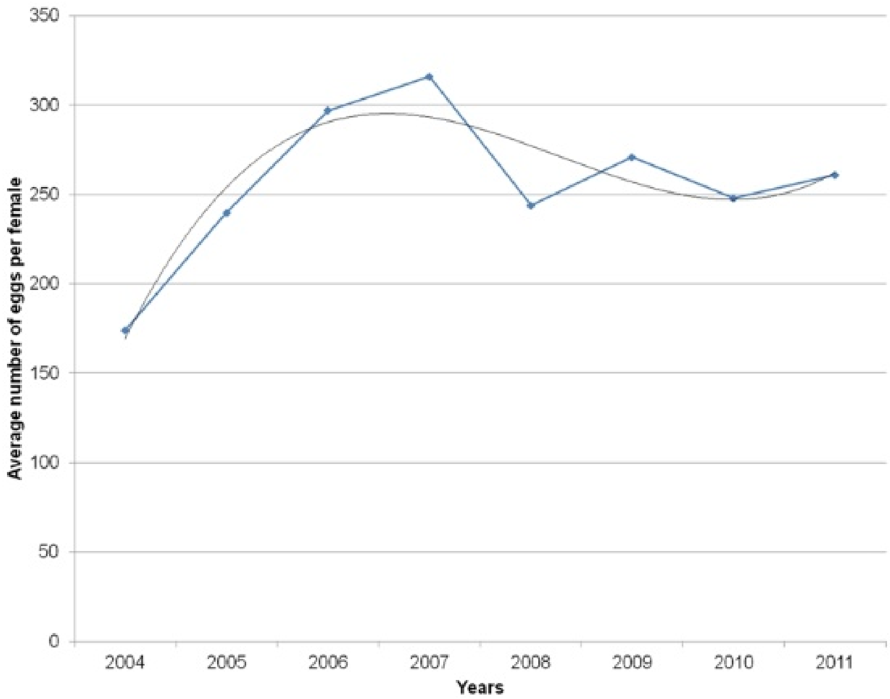

Figure 4. Dynamics of fertility of narrow-clawed crayfish's females in Lake Sevan during the period 2004-2011

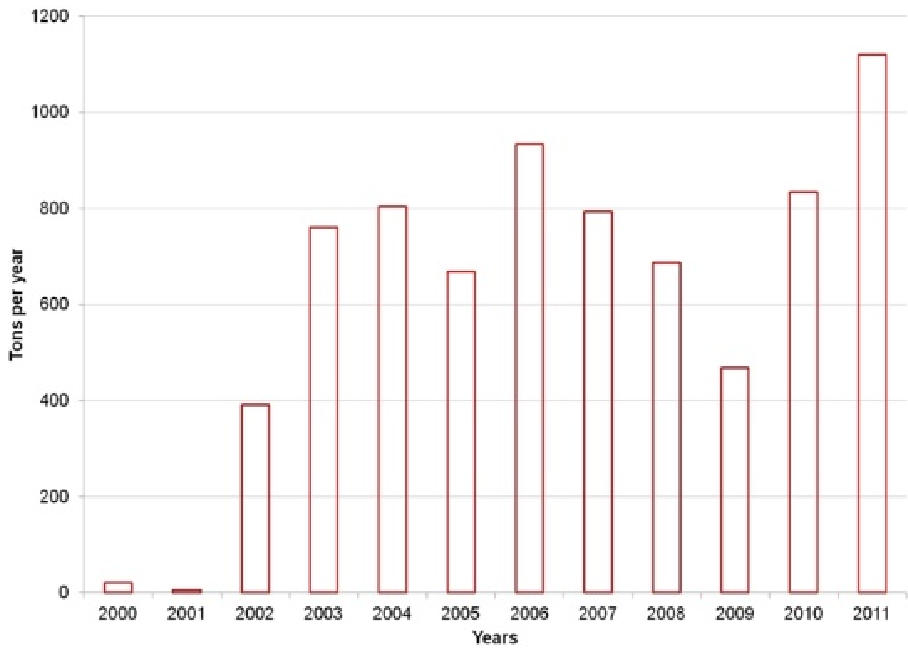

Figure 5. Dynamics of export volume of narrow-clawed crayfishes from Armenia during the period 2004-2011

The existing approach in capturing of the crayfishes might cause significant decline of its population in a mid-term perspective. Assuming that nothing becomes changed in the crayfish capturing policy during next decades, the equation of the first logarithmic model (see figure 2) can be applied for the forecasting the industrial stock. The application of the equation shows that there is a relatively high probability that in 2021 the industrial volume of crayfishes in the Lake Sevan will become below 500 tons, and that means decrease of the crayfish's population at the Lake on more than 70% during 17 years.

If the conditions causing the observed decline of crayfish population remain the same, the following major consequences have to be expected from the forecasted population decline. First group of consequences is related economic aspects of crayfish harvesting. At current the narrow-clawed crayfishes are the only seafood product that is exported to countries of European Union and North America (Statistical yearbook of Armenia 2008, 2012), which have high food safety and quality standards. At current there are more than twenty enterprises harvesting crayfishes, the export makes more than 15 millions USD per annum (Statistical yearbook of Armenia 2012). Significant decline of resource will cause collapse of some enterprises and decrease of export volume.

The second group of consequences which is not that obvious is related to the feeding behavior of crayfishes. In Lake Sevan the narrow-clawed crayfishes are mainly detritivores, and they consume the benthic deposits thus preventing increase of organic pollution which might intensify the eutrophication of the Lake. The Lake Sevan is surrounded by four towns and 36 villages; it is one of the major resorts of Armenia that hosts tourists in the hotels based at the shore of the Lake. In addition it is surrounded by fields of potato, cabbage, and grains, which are consistently fertilized. The sewage and the fertilizers are the big sources of nitrogen and phosphorus. Consistent supply of the Lake with fairly constant amount of phosphates and nitrates in terms of decrease of detritivore might have negative effect on the Lakes conditions and the water quality. Further investigations aimed at comparing the concentration of nutrients with other biotic parameters and modeling of the nutrient transfer processes will allow understanding the character and the scale of ecological consequences as well as preliminary determination of the time frame for the mitigation.

Conclusion

Observed decline of the population of narrow-clawed crayfish at Lake Sevan has statistical significance. Most probable cause of the decline is the overharvesting. In the scenario when no changes in harvesting policy are made, most probable consequences of overharvesting are decline of its population by more than 70% in the next 17 years, and decline of industrial stock to a volume below 500 tons. It will have negative economic and ecological consequences. Economic consequences are related to decrease of export volume of crayfishes from Armenia. Ecological consequences are related to imbalance in the transfer of nutrients. Further investigations on modeling of the ecological processes can provide better understanding of the ecological consequences and their mitigation.

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