Трансформация экосистем
Ecosystem Transformation
www.ecosysttrans.com

The features of narrow-clawed crayfish (*Pontastacus leptodactylus* Eschscholtz, 1823) population development in Lake Sevan during 1996–2018

Evelina Kh. Ghukasyan[1]*, Hranush F. Melkonyan[1, 2], Lilit G. Stepanyan[1], Norik S. Badalyan[1]

[1] *Institute of Hydroecology and Ichthyology of the Scientific Center of Zoology and Hydroecology, National Academy of Sciences of the Republic of Armenia, P. Sevak str. 7, 0014, Yerevan, Armenia*

[2] *Russian-Armenian University, H. Emin str. 123, 0051, Yerevan, Armenia*

**e_ghukasyan@yahoo.com*

Received: 13.05.2019
Accepted: 03.06.2019
Published online: 16.08.2019

DOI: 10.23859/estr-190513
UDC 574.52
URL: http://www.ecosysttrans.com/publikatsii/detail_page.php?ID=128

ISSN 2619-094X Print
ISSN 2619-0931 Online

The narrow-clawed crayfish, an invasive hydrobiont of Lake Sevan appeared in the lake due to accidental introduction having occupied almost the entire territory of Lake Sevan, finding favorable conditions for its existence. Investigation of the dynamics of narrow-clawed crayfish population development showed that since 2014 there has been a tendency in reduction of the crayfish population, which was the result of improper organization of the fishing process and deterioration of the ecosystem. Although the main factors limiting the distribution of crayfish in natural conditions are oxygen deficiency at great depths and the type of the bottom sediments, in recent years, the reason for reducing the stocks of narrow-clawed crayfish is the increased anthropogenic impact, in particular, the use of incorrect fishing gear.

Keywords: Lake Sevan, narrow-clawed crayfish, crayfishing, commercial stocks.

Ghukasyan, E.Kh. et al., 2019. The features of narrow-clawed crayfish (*Pontastacus leptodactylus* Eschscholtz, 1823) population development in Lake Sevan during 1996–2018. *Ecosystem Transformation* **2** (3), 24–31.

Introduction

The socioeconomic problems of the Republic of Armenia directly influence the largest high-altitude freshwater waterbody in the South Caucasus – Lake Sevan, which occupies a unique place in the country's water balance. Today the volume of the lake is 38.27 km^3, and the area is 1279.18 km^2. The lake is divided into two parts differing from each other by their morphological, hydrological, hydrophysical and other parameters (Annual report…, 2018). The south-eastern part is occupied by shallow Big Sevan, the north-eastern part is Small Sevan with small slopes of the coast and greater depths (maximum depth 83.3 m). The average depth of the lake is 26.2 m (Fig. 1).

For centuries, Lake Sevan has been famous for high endemicity of its native fauna. However, in the recent years, a number of invasive species appeared in the lake, including the narrow-clawed crayfish (*Pontastacus leptodactylus* Eschscholtz, 1823), which has changed the structure of the biocenosis and trophic relationships (Gabrielyan and Ghukasyan, 2007).

The narrow-clawed crayfish can survive in a wide range of environmental conditions (Silver and Tsukerzis, 1964). Crayfish, appeared in Lake Sevan due to random introductions and found favorable conditions (Table 1), its population developed intensively and became an object of commercial fisheries (Ghukasyan and Hovhannisyan, 1999; Hovhannisyan and Ghukasyan, 1996).

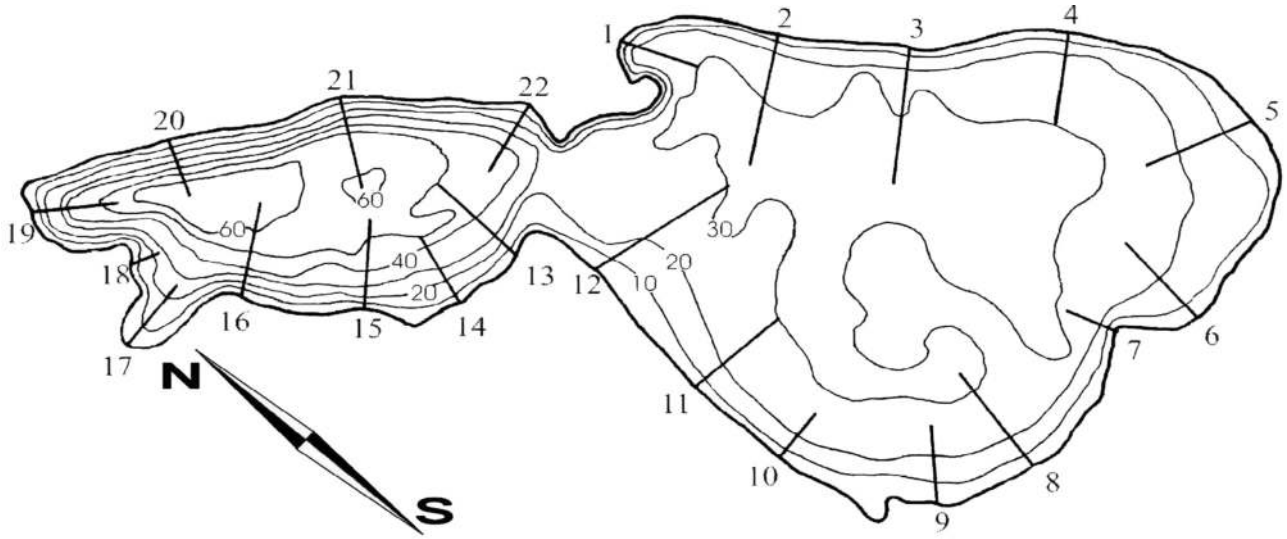

Fig. 1. The map of isobaths (in meters) of Lake Sevan with the locations of half-cuts where benthic saples were taken. 1 – Artanish, 2 – Babajdan*, 3 – Pambak*, 4 – Shishkaya, 5 – Gilli*, 6 – Arpa*, 7 – Tsovinar*, 8 – Zolachar*, 9 – Martuni, 10 – XIV station, 11 – Kulali, 12 – Sari-Kaya*, 13 – Gavaraget, 14 – Hayrivank*, 15 – Norashen*, 16 – Modelniy*, 17 – Lchashen*, 18 – Tsamakaberd*, 19 – Tsovagyugh*, 20 – Gyuney*, 21 – VI station*, 22 – Shorzha*. * – locations where crayfish was discovered.

However, the population of crayfish is under a strong anthropogenic influence, undergoing serious changes as a result.

The aim of this research is to study the dynamics of narrow-clawed crayfish population development in Lake Sevan and to identify factors affecting the crayfish.

Material and methods

The research of the commercially exploited population of crayfish includes the period of 1996 and 2004–2018. 10000 animals were examined to assess biological and population indicators of crayfish.

Sampling was carried out in different parts of Lake Sevan from a depth of 2–25 m using crayfish traps and fishermen nets. Sampling stations were opposite the following settlements – the peninsulas of Small Sevan: Tsamakaberd, Modelniy, Norashen, Lchashen, Hayrivank, Tsovagyugh, Gyuney, VI station, Shorzha – and Big Sevan: Sari Kaya, Babadjan, Zolachar, Tsovinar, Arpa, Pambak and Gilli.

Depth was chosen taking into account the limits of animal's distribution. The maximum depths on sampling sites are presented on figure 1 according to bathymetric map by Kireev (1933).

The biotopes most densely populated by crayfish and the limits of these biotopes in the lake were identified, their effective areas were calculated. When calculating the area suitable for crayfish habitation, the table of the bottom surface of Lake Sevan developed by Kireev (1933) was taken as a base to determine the possible limits of crayfish distribution.

The data on size (measurements were taken from telson to rostrum), age (the age of the crayfish was determined based on growth rates), size-age related and sex structure as well as physiological fecundity of the commercially exploited part of the population were obtained. The influence of habitat on biological indices of the commercial stock was studied.

The fecundity indices were evaluated annually for the same period, i.e. in June and July. The total number of eggs attached to the pleopods of caught crayfish was calculated and divided by the number of females.

The average mass of one egg was calculated in June and July, by weighing the eggs removed from different crayfish and dividing by their quantity. August is not included in the count since some individuals already carried the first larvae.

An assessment of the narrow-clawed crayfish commercial stocks was done using standard crayfish traps without bait (Budnikov, 1932). The allowable catch rate was set at 25% of the stock, minus the share of non-commercial size animals (with a length of up to 9 cm) in the fishing gear.

When working with traps we assessed the applicability of this type of fishing gear, the damage for population it causes and the activity of animals of different age groups. We used 50–100 traps simultaneously, setting them in several rows, to cover as much bottom area as possible.

Obtained data were used to evaluate crayfish stocks, as well as the selection of the appropriate methodology and localization of crayfish stocks.

Dissolved oxygen content was calculated using the Winkler's method (Lurye, 1971).

Results and discussion

The distribution, development and the population density of the narrow-clawed crayfish in all waterbodies including Lake Sevan are restricted by a number of factors, such as the character of the

Table 1. Indicators of aquatic ecosystems suitable for crayfish. The data on Lake Sevan are presented for depths of 0–25 m, the zone with maximum crayfish numbers and conditions most favorable for their survival (Badalyan, 2012).

Indicator	Optimal values necessary for the existence of crayfish (Fedotov, 1993)	Present conditions for the existence of crayfish in Lake Sevan
Water transparency	1–1.5 m	5–12 m
Oxygen content	5.4–9.1 mg/l	5.0–10.7 mg/l
pH	6–10	7.1–9.6
Water hardness	5–8°	5–6.5°
Carbon dioxide	up to 10 mg/l	–
Hydrogen sulphide	0	0
Ammonium	1.0 mg/l (summer), 0.5 mg/l (winter)	0.2–0.4 mg/l
Nitrate	< 40 mg/l	0.02–0.17 mg/l
Nitrite	< 0.01 mg/l	0.02–0.03 mg/l
Total iron	0.36–1.0 mg/l	0.02–0.09 mg/l
Chlorine	up to 5.0 mg/l	–
Total Calcium	10–60 mg/l	21–27 mg/l
Salinity	up to 3 g/l for southern lakes	0.5–0.7 g/l
Depth	more than 4–5 m, less than 10–15 m	0.5–25 m
Ground	clay, sand, peat, limestone	sand, sand-silt, silt

bottom sediments, temperature fluctuations, oxygen deficiency, population density and other parameters (Aydin and Dilek, 2004; Breithaupt, 1998; Fedotov, 1993; Mackeviciene et al, 1995; Pronina, 2009).

The bottom sediments of Lake Sevan are represented by sand to the depth of 2–4 m, while silt is the dominating type of the bottom sediments at the depth of 4–7 m in Small Sevan and at a depth of 7–10 m in Big Sevan, further replaced by sandy silt (at 7–10 m and 10–15 m, respectively), while the brown (15–20 m) and black silt (at a depth of 20 m and below) dominate in deeper layers with their characteristic odor of hydrogen sulfide.

In the sandy coastal areas, crayfish are found in strictly limited quantities. The reason being the deficit of food and limited habitat area. The preferred substrate for crayfish is sandy silt. Due to the deterioration of oxygen conditions and the soft bottom sediments crayfish are virtually absent at greater depths.

Long-term studies of the spatial distribution of narrow-clawed crayfish in Lake Sevan have shown that these hydrobionts are mainly concentrated at depths of 5–15 m, where the sandy silt or solid silt is dominant. Oxygen conditions are the main factor limiting the spread of crayfish in Lake Sevan. The oxygen conditions at depths below 30 m are not favorable for crayfish (Table 2).

The share of crayfish with relatively small sizes (1–3 years) in the range from 3 to 7 m varies from 72 to 79%, then their numbers decrease gradually. The proportion of animals aged 4–6 years (9.9–13.3 cm) increases in parallel with increasing depth (Table 3). Larger individuals are found in limited numbers, preferring 9–15 m depths. Animals up to one year old are found in shallows covered with macrophytes.

Long-term studies of morphological indices of Lake Sevan crayfish have shown the presence of population rejuvenation trend since 1996. In 1996, the maximum sizes of crayfish in Lake Sevan were 18 cm for females and 23.5 cm for males (Mackeviciene et al., 1995). The average commercial size individuals in this area ranged from 12.5 to 12.8 cm. However, the maximum and average indicators of animals decreased, gradually (Table 3). The modal size groups of crayfish population in Lake Sevan in 2017 were individuals with a length of 8.4–12 cm, the maximum sizes of males and females were 13.6 and 13.8 cm, respectively.

Table 2. Dissolved oxygen contents in different parts of Lake Sevan at depths of 15–30 m (in summer).

Sampling station	Depth 15 m		Depth 25–30 m	
	O_2, mg/l	pH	O_2, mg/l	pH
Gyuney	7.2	–	3.66	7.3
VI station	7.3	–	3.60	7.2
Shorzha	–	–	3.67	7.3
Sari-Kaya	7.75	8.2	4.46	7.9
Babadjan	4.2	7.6	4.32	7.3
Gilli	8.35	7.8	5.44	7.3
Tsovinar	6.5	7.7	4.2	7.1
Hayravank	7.8	7.6	5.28	7.3

Table 3. Changes in the linear indices of the commercial stock of narrow-clawed crayfish in 1996–2018.

Year	Average length, cm	Average mass, g
1996	12.65 ± 0.15	66.3 ± 6.5
2004	10.7 ± 0.25	38.5 ± 6.5
2005	10.5 ± 0.50	35.5 ± 11.0
2006	11.5 ± 1.0	48.3 ± 10.5
2007	11.5 ± 1.41	45.0 ± 12.3
2008	11.0 ± 1.23	39.5 ± 13.1
2009	11.2 ± 1.2	39.8 ± 11.0
2010	10.6 ± 1.39	36.8 ± 13.1
2011	11.1 ± 1.85	44.7 ± 11.0
2012	10.4 ± 0.7	35.2 ± 8.5
2013	10.7 ± 1.2	37.3 ± 13.0
2014	10.6 ± 0.8	37.8 ± 9.5
2015	10.3 ± 0.8	34.0 ± 8.5
2016	10.1 ± 0.7	29.0 ± 7.2
2017	9.6 ± 0.7	30.0 ± 7.0
2018	9.1 ± 1.5	23.0 ± 5.0

Reduction of the linear sizes of animals and declining number of large individuals indicates that the latter are under an increased fishing impact.

A study of the sex structure of the crayfish population in Lake Sevan showed that the ratio of males and females in the lake is 1:1.

The temperature is the main factor regulating the process of crayfish reproduction. The process of crayfish spawning in Lake Sevan usually begins in March when surface water temperature is within 4–6.5 °C. Studies carried out in 2018 showed that the mild winter of 2017–2018 has affected the development cycle of crayfish. Their reproduction in 2018 began since February, a month earlier than in previous years, when the surface water temperature was again 6 °C, while in 2017, due to continuous freezing of the lake the females with fertilized eggs were recorded in April.

In 1994–1995 the average physiological fecundity of the crayfish was 278 eggs, the average length of the breeding females was 12.2 cm, the limits of the change in the physiological fecundity were 116–632 eggs, the egg mass ranged from 10.2 to 11.3 mg (Hovhannisyan and Ghukasyan,1998) (Fig. 2).

During 1996–2018 the mean fecundity ranged from 224 to 318 egg/individual (Alekhnovich and Ghukasyan, 2013; Ghukasyan et al., 2006). No specific patterns of changes in fecundity indices were observed, however, a decrease in the average size

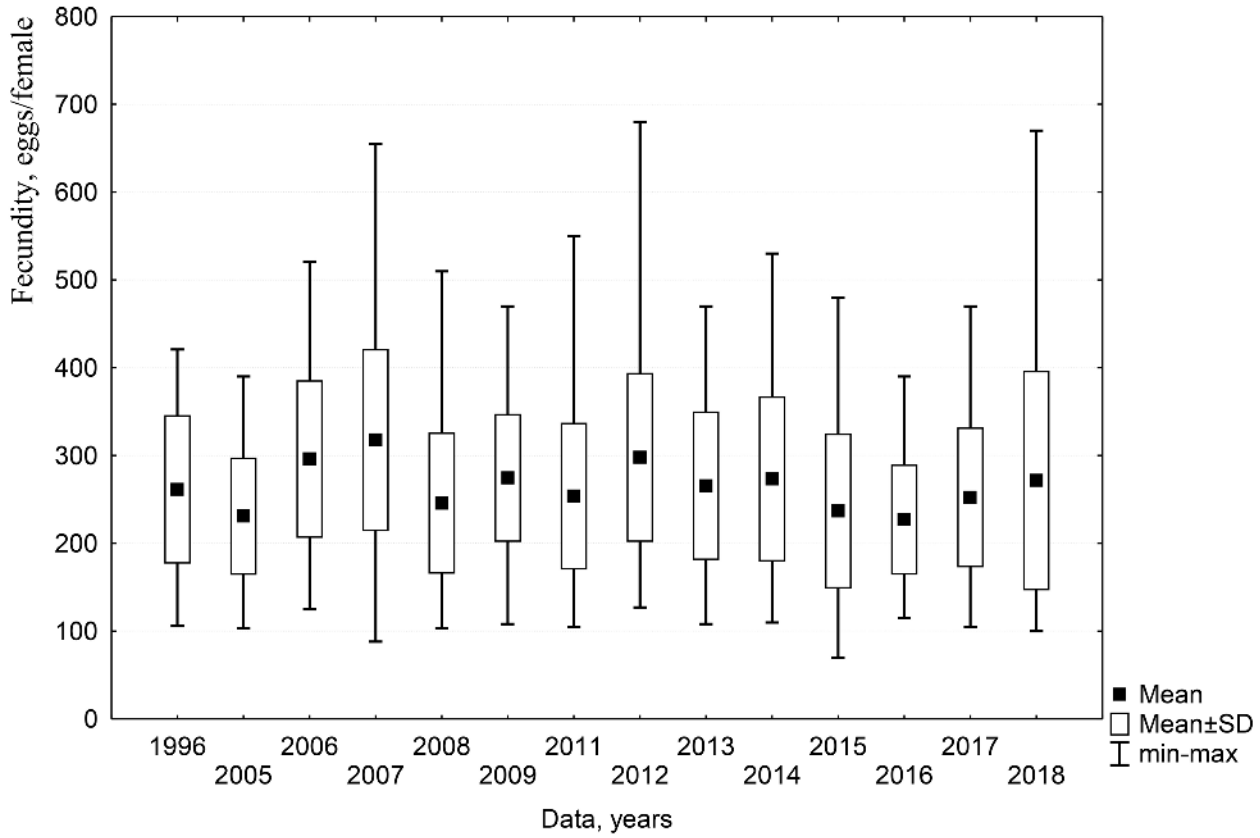

Fig. 2. Dynamics of fecundity (eggs/female) indices of crayfish during the period of 1996–2018.

of breeding females was recorded. The average size of breeding female was 12.2 cm in 1996, decreasing down to 10.5 ± 0.50 cm in 2005, the mean fecundity decreased from 390 to 103 eggs, respectively. In 2005, the average weight of one egg was 15.5mg.

Fecundity indices were relatively high in 2006, 2007 and 2012. Mean fecundity in 2016 has slightly changed compared with the previous year. The average fecundity of crayfish was 237 eggs in 2015. The average weight of the fertilized egg was 11.6 mg. The size of the female varied from 8.5 to 13.8 cm. In 2016, 8.8–13.1 cm individuals of 3–6 years old took part in reproduction, the mean fecundity was 227 eggs/individual, but there was a tendency of a decrease in fecundity compared with the previous year in all age groups (Table 4). The weight of one egg was 12.2 mg.

Fecundity indices of crayfish of different age groups recorded in 2015, 2016, 2018 are given below (Table 4).

In 2018 the minimum length of crayfish breeding female was 8.2 cm, and the maximum was 13.3 cm. The average length was 10.6 cm, the mean fecundity was 270 eggs, the minimum and maximum observed fecundities were 100 and 670 eggs. In 2018, fecundity did not decrease with the age of the animals. The latter indicates that the animals in the lake have not reached the age when fecundity decreases due to physiological reasons as a result of stock overexploitation.

Studies of reproductive indices showed that the growth trend of fecundity in all age groups has been going on since 2016 (Table 4). In 2015, mean fecundity of one female was 237 eggs, in 2016 it was

Table 4. The fecundity indices of different age groups of crayfish in 2015, 2016, 2018.

Age, year (length, cm)	Mean fecundity, eggs/ind.			Minimum fecundity, eggs/ind.			Maximum fecundity, eggs/ind.		
	2015	2016	2018	2015	2016	2018	2015	2016	2018
3 (8.4–9.8)	175 ± 45	161 ± 33	199 ± 83	70	115	100	290	220	430
4 (9.9–10.9)	251 ± 63	261 ± 61	255 ± 119	180	160	105	415	305	540
5 (11.0–12.0)	311 ± 56	254 ± 51	334 ± 126	170	165	141	430	350	670
6 (12.1–13.3)	351 ± 53	297 ± 87	358 ± 111	210	160	195	429	390	550

Table 5. The average annual growth rate of the narrow-clawed crayfish population in Lake Sevan.

Age, year	2	3	4	5	6	7
Growth rate, g/year	11.52	13.07	12.27	10.22	8.06	6.27

227 eggs, in 2017 it was 260 eggs and in 2018 it was 270 eggs (Fig. 2). In 2018 the average weight of fertilized egg was 10.2 mg.

The appearance of first crayfish larvae in the lake for almost the entire period of studies was recorded from June to July when the water temperature exceeded 17 °C. In 2017, the mortality of the fertilized eggs was 57%, in 2018 it was 67.5%. In 2004 the weight of the first larva was 24.5 ± 5.45mg, in 2018 it was 22.5 ± 5.45 mg.

Studies of the growth characteristics of crayfish of Lake Sevan showed that the ratio of the length of crayfish (*L*, cm) and mass (*W*, g) is expressed by the following formula:

$$W = 0{,}041L^{2{,}852},\ R^2 = 0{,}92$$

The average annual growth rate of crayfish in Lake Sevan was 10.23 ± 2.62 g.

The commercial exploitation was mainly associated with animals of 4 years and older (Alekhnovich and Ghukasyan, 2016).

The maximum annual mass increase in crayfish of Lake Sevan was registered at the age 3 years old. Our studies have shown that crayfish growth slows down with age.

Sampling in various areas of Lake Sevan has shown that 3–5-year-old animals constitute the modal age group of the commercially exploited part of the crayfish population in almost all areas (Table 5).

Assessment of commercial and consumed crayfish stocks

In order to assess the impact of the extraction on the narrow-clawed crayfish population of Lake Sevan, each year a study of the size and age structure was

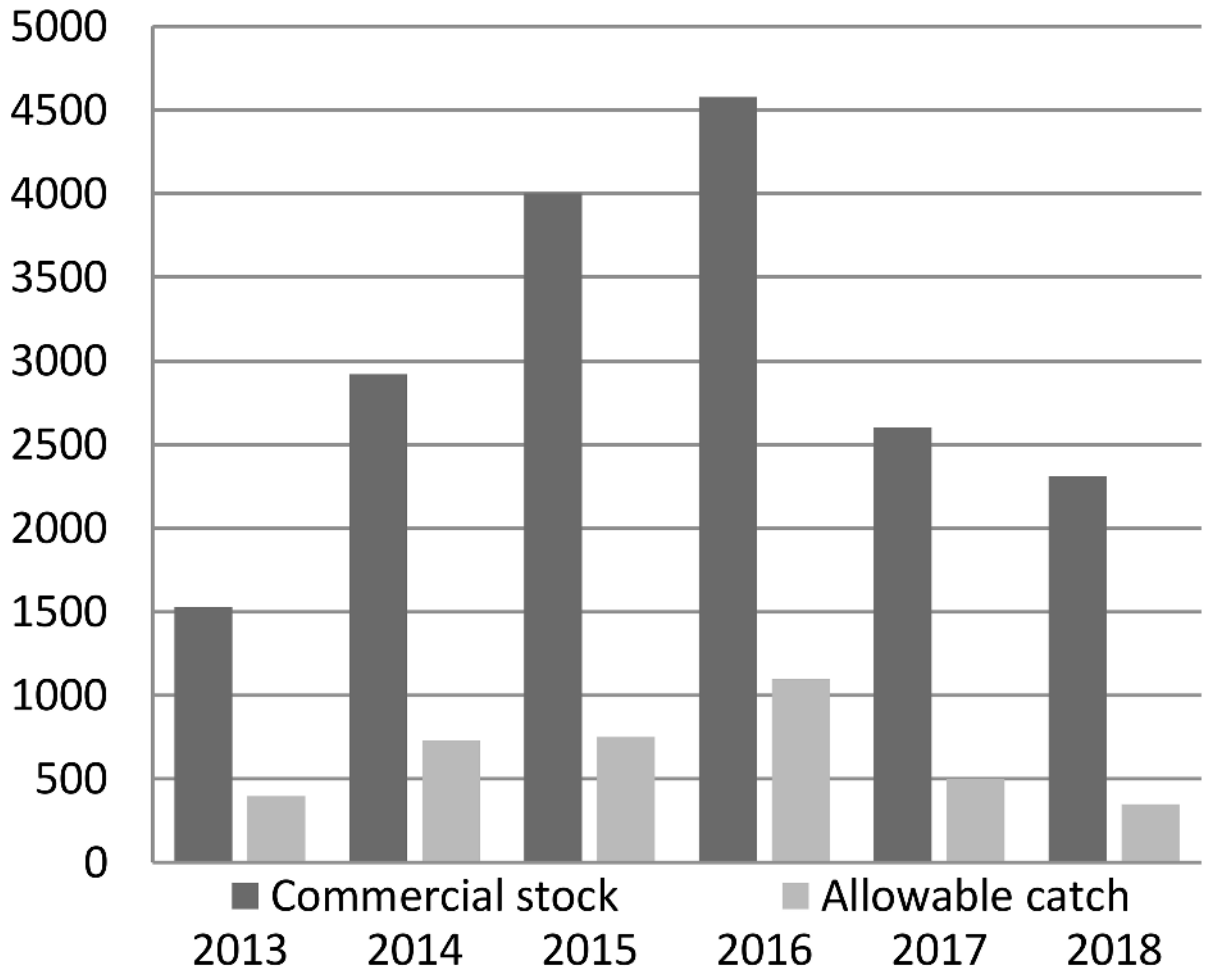

Fig. 3. Dynamics of commercial stocks and allowable catch of narrow-clawed crayfish in Lake Sevan in 2013–2018 (Annual reports…, 2013–2018).

conducted for the crayfish caught by various means of fishing. Caspian crayfish traps were used in Lake Sevan from 2004 to 2014, where the proportion of commercial-sized animals was up to 10% (Ghukasyan et al, 2010; 2016a). From 2014 to the present day, commercial fishermen use folded and spring-loaded crayfish traps. The use of passive fishing equipment produces a negative impact on the crayfish population.

The share of spring-loaded crayfish traps in 2017 was about 22%, in 2018 it increased to 38%. The average amount of non-commercial size animals caught with folded crayfish traps in 2017 was 46.7% in 2017 and 56% in 2018.

When such fishing gear is used, the population becomes deprived of the possibility of replenishment and restoration, resulting in a risk of annual reduction of commercial stocks.

In 2018, crayfish studies have shown that the continuing trend of narrow-clawed crayfish stocks decreases in the lake. In 2015, the average catchability of a single spring-loaded crayfish trap was 281 g, in 2016, the same indicator was 333 g, whereas in 2017 and 2018 the average hunting power of a crayfish trap was 154 g and 125 g, respectively. Note that in 2017, the commercial stock of crayfish in Lake Sevan was 2600 tons, in 2018 it is a lower than 2312 tons (Fig. 3).

The allowable catch rate was 25% of the commercial population. In some years, when the number of non-commercially sized animals in the catch was too large the percentage value of the allowable catch decreased. A disease has spread among the crayfish population in recent years, causing a reduction in the number of these animals. However, the constant decline in crayfish stocks is mainly caused by poorly controlled fishing (Ghukasyan et al, 2016b).

Lake Sevan in 2018 is considered a lake of average productivity in terms of crayfish productivity. The state of the crayfish population of Lake Sevan is deteriorating every year. Commercial stocks of the aforementioned hydrobionts are declining. In view of the need for the development of new industries based on the use of rapidly renewed natural resources for the Republic of Armenia, the problem of scientific management of crayfish production in Lake Sevan has become a priority.

Acknowledgements

This work was supported by the RA MES State Committee of Science, in the frames of the research project N 1-15/TB “Carological investigations of the state of lake ecosystem having strategically important for Armenia and of its bioresources in the conditions of climate change and lake Sevan level rise”.

References

Alekhnovich, A.V., Ghukasyan, E.Kh., 2013. Razmernaja struktura, dinamika polovogo sozrevanija i plodovitost dlinnopalogo raka *Astacus leptodactylus* vodoemov Belarusi i Armenii [The size structure, sexual maturation dynamics and the fertility of long-clawed crayfish species *Astacus leptodactylus* in the water objects in Belarus and Armenia]. *Gidrobiologicheskij jurnal [Hydrobiological journal]* **5**, 54–66. (In Russian).

Alekhnovich, A.V., Ghukasyan, E.Kh., 2016. Zakonomernosti rosta dlinnopalogo raka belorusskogo oz. Sominskoe i armjanskogo oz. Sevan [Comparative analysis of the narrow-clawed crayfish growth patterns in Lake Sominskoe in Belarus and in Lake Sevan in Armenia]. *Doklady NAN Belarusi [Reports of the National Academy of Sciences of Belarus]* **60** (3), 105–107. (In Russian).

Annual reports of the project “Fish and crayfish stock assessment in Lake Sevan and its basin”. Ministry of Nature Protection of the Republic of Armenia, 2013–2018. (In Armenian).

Annual report of the Service of the Hydrometeorology and Active Influence on Atmospheric Phenomena of the Ministry of Emergency Situations of the Republic of Armenia “Water balance of Lake Sevan”, 2018. (In Armenian).

Aydin, H., Dilek, M.K., 2004. Effects of different water temperatures on the hatching time and survival rates of freshwater crayfish (*Astacus leptodactylus* Eschscholtz, 1823) eggs. *Turkish Journal of Aquatic Sciences* **4**, 75–79.

Badalyan, N.S., 2012. The growing features of *Pontacus leptodactilus* Eschch. of Lake Sevan. *Biological journal of Armenia* **1** (64), 108–110. (In Armenian).

Breithaupt, T., 1998. Crayfish habitats and chemo-orientation. *Abstracts of the 12-th International Symposium International Association of Astacology.* Augsburg, Germany, 29 p.

Budnikov, K.N., 1932. Rak, evo razvedenie i promysel [Crayfish, its breeding and fishing]. All-Union United Cooperative Publishing House, Moscow, Russia, 209 p. (in Russian).

Fedotov, V.P., 1993. Razvedenie rakov [Crayfish Breeding]. Biosvjaz, St Petersburg, Russia, 108 p. (In Russian).

Gabrielyan, B.K., Ghukasyan, E.Kh., 2007. Ecologicheskie posledstvija introdukcii gidrobiontov v ozero Sevan [Ecological consequence of introduction hydrobionts into Lake Sevan]. *Abstracts of reports of International scientific conference “Natural and Invasive Processes of*

Biodiversity of Water and Ground Ecosystems Formation" [Tezisy dokladov Mezhdunarodnoy nauchnoy konferentsii "Estestvennye i invaziynye protsessy formirovaniya bioraznoobraziya vodnykh i nazemnykh ekosystem"]. Rostov-on-Don, Russia, 81–82. (In Russian).

Ghukasyan, E.Kh., Alekhnovich, A.V., Badalyan, N.S., Asatryan, V.L., Sahakyan, S.Q., 2016a. The process of freshwater crayfish harvesting and its possible consequences in Sevan and Sominsk Lakes. *Electronic Journal of Natural Sciences of National Academy of Sciences of Republic Armenia* **27** (2), 13–17.

Ghukasyan, E.Kh., Badalyan, N.S., Khosrovyan, A.M., Aleksanyan, H.A., 2016b. Dinamika populjacionnykh parametrov dlinnopalogo raka *Pontastacus leptodactylus* Eschscholtz, 1823 v uslovijah povyshenija urovnja vody [Dynamics of population parameters of long-clawed crayfish *Pontastacus leptodactylus* Eschscholtz, 1823 under the conditions of water level rise]. In: Krylov, A.V. (ed.), *Ozero Sevan. Ekologicheskoe sostojanie v period izmenenija urovnja vody [Lake Sevan. Ecological state during the period of water level change].* Filigran, Yaroslavl, Russia, 204–207. (In Russian).

Ghukasyan, E.Kh., Badalyan, N.S., Hovhanissyan, R.R., Dallakyan, M.S., 2006. On the changes of biological parameters of crayfish in the Lake Sevan. *Biological journal of Armenia* **58** (3–4), 321–324. (In Armenian).

Ghukasyan, E.Kh., Badalyan, N.S., Sahakyan, D.L., 2010. Ecologicheskie osobennosti dlinnopalogo raka v ozere Sevan i dinamika ego promyslovykh zapasov [Ecological features of long-clawed crayfish in Lake Sevan and dynamics of its commercial stocks]. In: Krylov, A.V. (ed.), *Ekologija ozera Sevan v period povyshenija ego urovnja. Rezultaty issledovanij Rossijsko-Armjanskoj biologicheskoj ekspedicii po gidroekologicheskomu obsledovaniju ozera Sevan (Armenia) (2005–2009 gg.) [Ecology of Lake Sevan during the period of water level rise. The Results of Russian-Armenian biological expedition from hydroecological survey of Lake Sevan (Armenia) (2005–2009)].* Nauka DSC, Makhachkala, Russia, 224–228. (In Russian).

Ghukasyan, E.Kh., Hovhannisyan, R.H., 1999. Dlinnopalyj rak *Pontascus leptodactylus* Esch. v vodoemakh Armenii [The narrow-clawed crayfish *Pontastacus leptodactylus* Eschscholtz in the reservoirs of Armenia]. *Tezisy dokladov Mezhdunarodnoj nauchnoj konferentsii "Ozyornye ekosystemy: biologicheskie protsessy, antropogennaya transformatsiya, kachestvo vody" [Abstracts of reports of International scientific conference "Lake Ecosystems: Biological Processes, Anthropogenic Transformation, Water Quality"].* Minsk, Belarus, 101. (In Russian).

Hovhannisyan, R.H., Ghukasyan, E.Kh., 1996. Some ecological peculiarities of Lake Sevan Higher Crustacean, *Pontastacus leptodactylus* Esch. *Proceedings of the international conference "Lake Sevan: problems and strategies of action".* Sevan, Armenia, 99–101.

Hovhannisyan, R.H., Ghukasyan, E.Kh., 1998. K ocenke transformacii organicheskih veshestv v ozere Sevan vysshimi rakoobraznymi [To assessment of the transformation of organic matter in Lake Sevan by higher crustaceans]. *Tezisy dokladov respublikanskoy nauchnoy konferencii po zoologii [Abstracts of the Republican Scientific Conference of Zoology].* Yerevan, Armenia, 88–89. (In Russian).

Kireev, I.A., 1933. Gidrograficheskie raboty na oz. Sevan [Hydrografical works on Lake Sevan]. *Materialy po issledovaniju oz. Sevan i ego bassejna. T. V. [Materials of study of Lake Sevan and its basin. Vol. 5.].* Sovetskiy Pechatnik, Leningrad, USSR, 130 p. (In Russian).

Lurye, Ju.Ju, 1971. Unificirovannye metody analiza vod [Unified methods of water analysis]. Khimiya, Moscow, Russia, 375 p. (In Russian).

Mackeviciene, G., Tamkeviciene, E., Mickeniene, J,. 1995. Nekotorye ekologo-fiziologicheskie uslovija obitanija rechnykh rakov v akvakulture [Some eco-physiological conditions of the habitat of freshwater crayfish in the aquaculture]. *Sbornik nauchnykh trudov GosNIORKh [Proceedings of Berg State Research Institute on Lake and River Fisheries]* **314**, 321–324. (In Russian).

Pronina, G.I., 2009. Vlijanie jestkosti sredy na sostojanie kletochnogo immuniteta rechnykh rakov [The impact of environment stiffness on the state of cellular immunity of freshwater crayfish]. *Bulletin of Moscow Society of Naturalists* **114** (3), 283–284. (In Russian).

Silver, D., Tsukerzis, Y.M., 1964. Chislo chromosom dlinnopalogo raka [Number of chromosomes in long-clawed crayfish]. *Citologiya [Cytology]* **5** (6), 631–633. (In Russian).