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V. V. Sadomskiy[1], E. G. Krupa[2], I. M. Aminova[3]

[1]"SED" LLP, Almaty, Kazakhstan,
[2]Republican State Enterprise "Institute of Zoology", Almaty, Kazakhstan,
[3]"Akjayik" State Nature Reserve, Atyrau, Kazakhstan.
E-mail: sadomsky@list.ru, elena_krupa@mail.ru, agrimony92@mail.ru

EXPERIMENTAL SURVEYS OF SEISMIC-ACOUSTIC IMPACT ON THE NORTH CASPIAN AQUATIC ORGANISMS

Abstract. Materials of experimental and field surveys of seismic-acoustic impact on the North Caspian zooplankton, zoobenthos and ichthyofauna in summer, 2012-2013 are provided in this article. The article also demonstrates that for assessment of seismic exploration impact, the following is of high indicator value: proportion of traumatized or dead specimens, the values of Shannon-Wiener diversity index and the value of an average individual mass of the specimen in hydrocoenoses. The highest proportion of the traumatized and/or dead specimens was recorded in plankton and benthic invertebrates populations in the course of experimental tests at a distance of 1m and 5m from the seismic SP. At the same period, a deviation of the Shannon-Wiener diversity index values and average individual mass of the specimen from background values was recorded in the both communities. Species composition of ichthyofauna was characterized by a high level of similarity throughout all stages of the surveys implemented. The lowest indicators of diversity (number of species, values of Shannon-Wiener diversity index) and fish numbers were recorded during seismic exploration. An increased average individual mass of a specimen in ichthyocoenoses together with the reduced numbers during seismic exploration may indicate the avoidance of unfavorable zone by younger fishes.

Key words: zooplankton, zoobenthos, fishes, seismic acoustics, air gun, seismic surveys.

An intense seismic exploration aimed at development of oil fields is causing the increased anthropogenic load on the entire Caspian Sea ecosystem [1]. Currently published data on assessment of seismic-acoustic impact do not present the level and scope of its effect on various groups of aquatic organisms constituting the relevance of this article [2-8].

Experimental study of seismic-acoustic effects on aquatic communities was implemented in two North Caspian areas (Figure 1) in June, 2012 and August, 2013. Three studies – before impact (background level, stage 1), during pneumatic source impact (experimental tests, stage 2) and after completion of seismic exploration impact (stage 3). To evaluate the impact of seismic acoustic effects on behavioral response of fish fauna, the composition and quantity of bento-pelagic fish communities were studied throughout all stages of seismic surveys.

Selection and processing of zooplankton, zoobenthos and fish fauna samples were performed using standard methods [1-5]. At all stages of the surveys, proportion of injured and/or dead specimens was studied in the populations of plankton and benthic invertebrates.

During experimental tests, cages with the fish and zooplankton samples caught in advance were placed at the depth of 3-4 m and at a distance of 1 m, 5 m and 10 m from the pneumatic source (Figure 2). In order to maintain the relative accuracy in the distance between the pneumatic source and cages setting

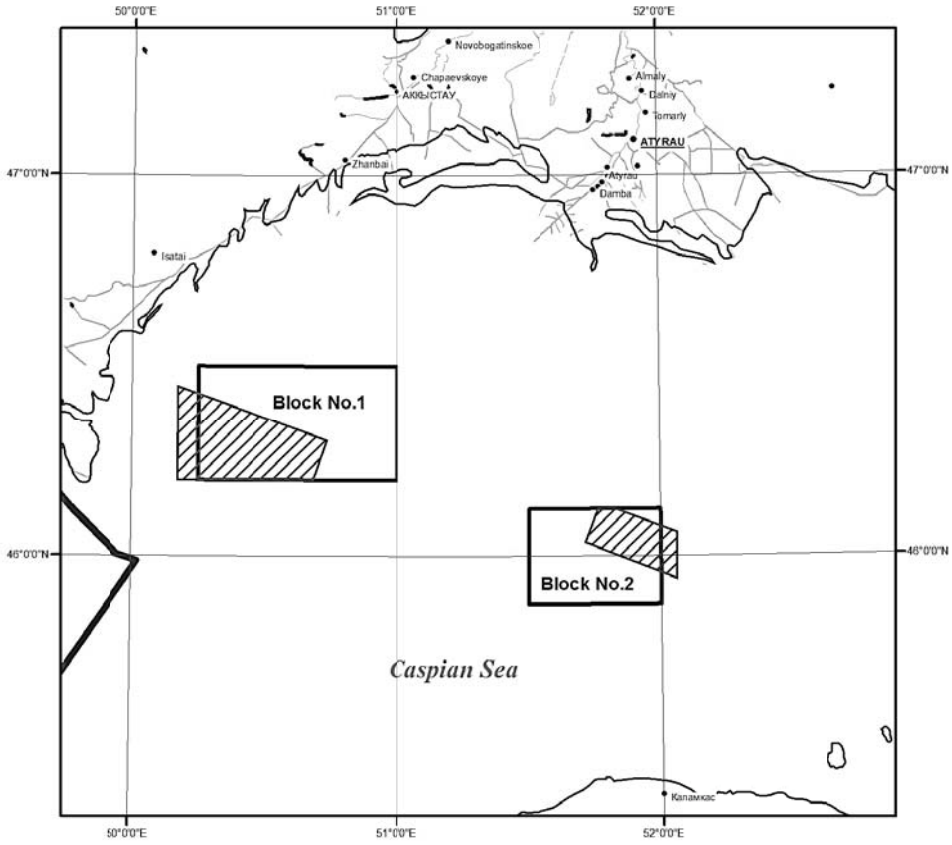


Figure 1 – Layout of test sites according to the assessment of the impact seismic survey on the North Caspian aquatic organisms

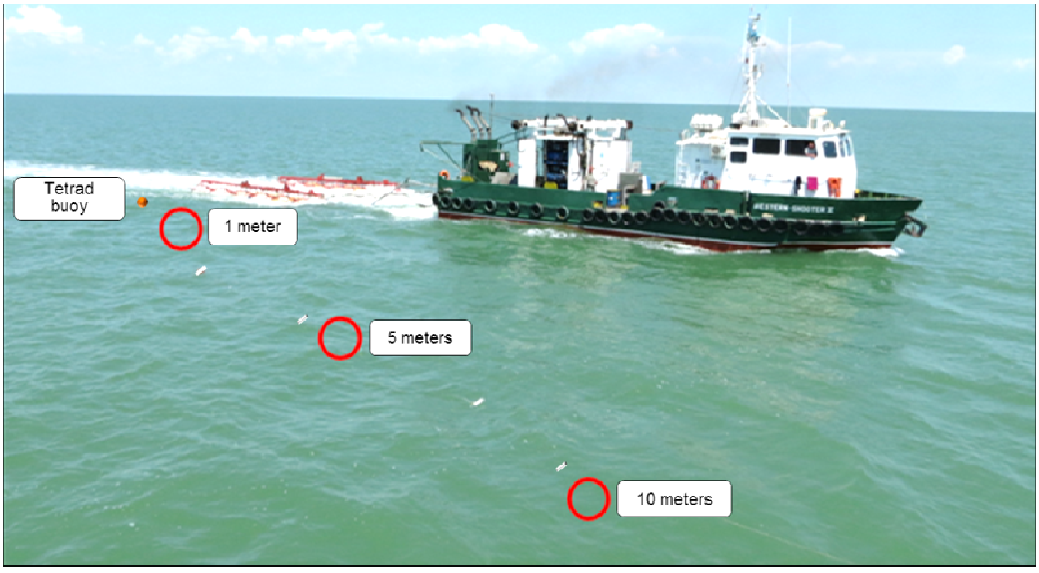


Figure 2. Scheme of the location of stations to study the impact of seismoacoustics on aquatic organisms

points, a seismic-acoustic excitation signal was performed by the pontoon device towed by shooter at the time of its passage through the reference buoy. Sediment samples with zoobenthos were collected on reference stations within 15 minutes after the pneumatic source seismic acoustic signals.

Hydrological and hydro-physical parameters were registered simultaneously with the experimental tests.

The experimental areas were characterized by shallow depths with similar hydrophysical and hydrochemical characteristics (Table 1). The sediments were presented by terrigenous sediments with sand fraction dominated (76.5-54.6%) (0.05-1.0 mm) [6].

Table 1 – Hydrological and hydrophysical indicators on experimental areas

Areas	Depth, m	Transparency, m	Temperature, °C	Water salinity, ‰	Turbidity, NTU	pH	Flow rate, m/sec
Area No.1, June 2012	6.5	1.0	26.6	5.1	9.06	7.7	9-11
Area No.2, August 2013	5.1	0.7	24.8	6.0	8.9	8.4	7-13

The diversity of zooplankton was ranged from 23 to 50 taxa. The background was typical of the Caspian Sea species: rotifers *Brachionus quadridentatus, B. plicatilis, Filinia longiseta*; cladocerans *Cornigerius maeoticus hirsus, Podonevadne camptonyx, P. angusta, P. trigona, Cercopagis pengoi;* copepods *Acartia tonsa, Calanipeda aquedulcis:* larvae *Cirripedia, Bivalvia, Hediste diversicolor;* crab *Rhitropanopeus harrisi.* The composition of the background species preserved substantial similarity throughout all stages of the surveys.

The number of species of planktonic invertebrates and their total number in the background conditions and after impact were characterized by the same or similar values (Table 2). During the experimental tests, a low diversity and deviation of zooplankton abundance from the values obtained in stages 1 and 3 was according to the survey methodology – staying of experimental communities in isolated cages.

Table 2 – Structural indicators of the North Caspian zooplankton at various survey stages

Indicator	Background conditions	Experimental tests	After impact
[1]number of species	34	29	35
[2]number of species	19	10	18
[1]average abundance, thousand spec./m^3	43.5	110.0	53.9
[2]average abundance, thousand spec./m^3	95.6	31.0	71.7
[1]proportion of injured or dead specimens, %	0.5	10.8	0.7
[1]Shannon-Weaver index, bit/ spec.	2.12	1.84	2.14
[2]Shannon-Weaver index, bit/ spec.	1.94	2.36	1.86
[1]Shannon-Weaver index, bit/mg	1.88	2.32	2.05
[2]Shannon-Weaver index, bit/mg	0.74	0.44	1.27
[1]average individual masse, mg	0.0051	0.0045	0.0051
[2]average individual masse, mg	0.0540	0.0100	0.0470
Note: numerals indicate the corresponding areas.			

Relative indicators have most indicator significance – the proportion of injured or dead specimens, the values of diversity index of Shannon-Weaver and average individual weight of specimen. The proportion of injured or dead specimens in the plankton populations of invertebrates at the background level, and after the impact was approximately the same, or lowers than at the time of impact seismoacoustics. The incidence of dead and/or injured specimens of copepod *Calanipeda aquedulcis* and *Acarcia tonsa* at all stages of the surveys was close in value to the other species, except for *H. diversicolor* polychaete and *B. plicatilis* rotifers, incidence of dead and/or injured specimens was higher during impact.

Analysis of the spatial distribution showed that the proportion of injured and/or dead planktonic invertebrate species was highest at a distance from the pneumatic source from 1 to 5 m. At a distance of 10 meters, it decreased with varying intensity, but did not reach background values (Figure 3).

The dynamics of the Shannon-Weaver index at each area had its own characteristics (Figure 4). The values of the indicator, according to the number of types of proportion in the total population (bits/sp.), in the background period and after the impact of seismic operations on both areas did not differ. Thus, during the experimental tests, the index value recorded in the area No.1 has decreased, and in the area No.2, in contrast, has increased with respect to the other two stages.

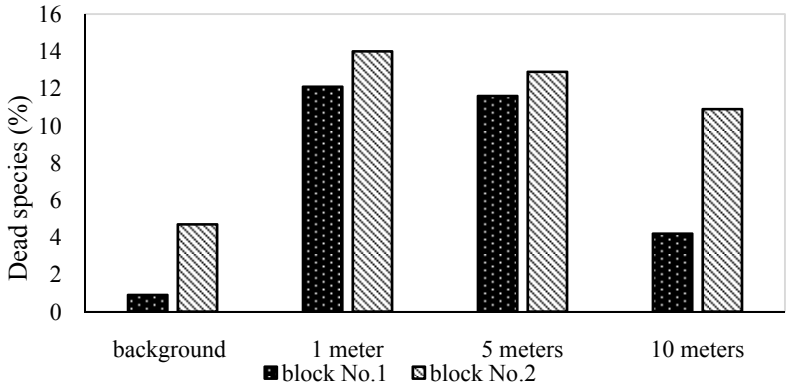


Figure 3 – Changes in proportion of injured and/or dead specimens in zooplankton at different distance from the pneumatic source

During the experimental tests, the dynamics of the second option of the index (bits/mg) was characterized by opposing trends: in the area No.1, it was positive, and in the area No.2, it was negative. At the same time, the indicator of relative background level was slightly higher than it was recorded after the impact completion.

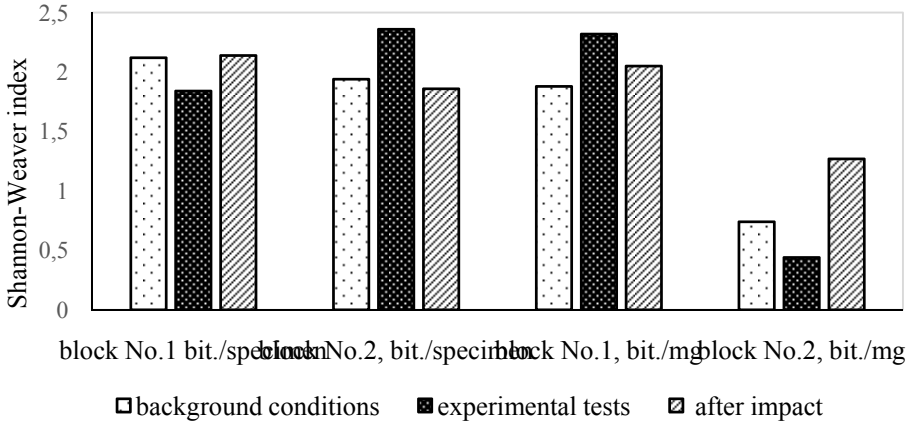


Figure 4 – The dynamics of the Shannon-Weaver index values at different stages of surveys of seismoacoustics impact on zooplankton

In both areas, the average mass of zooplankton decreased significantly in the period of impact and returned again to the background one or close to background values after completion.

The diversity of zoobenthos varied in the areas ranging from 16 to 26 species. The background was typical of the Caspian Sea species: worms *Hediste diversicolor*, *Oligochaeta gen. sp,* molluscs *Abra ovata, Cerastoderma lamarcki*; crustaceans *Stenocuma gracilis, S. graciloides, Pontogammarus (Obesogammarus) obesus,* and insect larvae.

The diversity and abundance of zoobenthos at various stages of surveys changed irregularly (Table 3). It can be explained by aggregation of distribution of benthic organisms. Proportion in the total number of benthic cenosis of dead and/or injured specimens was higher during the experimental work, with close values of the index recorded in background conditions and after impact of seismic exploration.

The proportion of dead and/or injured specimens in the populations of benthic invertebrates was highest in close proximity to the pneumatic source (Figure 5). The value of index decreased with the increasing distance from the source of impact, and at the same time, at a distance of 10 m, it remained above background levels.

The value of average weight of individual specimens in cenosis was the highest during the experimental tests.

Table 3 – Structural indicators of the North Caspian zoobenthos at various survey stages

Indicator	Background conditions	Experimental tests	After impact
[1]number of species	20	14	13
[2]number of species	14	15	10
[1]average abundance, thousand spec./m^2	1862	1810	1300
[2]average abundance, thousand spec./m^2	887	961	1294
[1]proportion of injured or dead specimens, %	1.8	2.6	1.9
[2]proportion of injured or dead specimens, %	0.5	1.5	0.8
[1]Shannon-Weaver index, bit/spec.	1.51	0.66	0.80
[2]Shannon-Weaver index, bit/spec.	0.96	1.09	1.02
[1]Shannon-Weaver index, bit/mg	1.17	0.60	0.88
[2]Shannon-Weaver index, bit/mg	0.74	0.73	0.62
[1]average individual masse, mg	7.75	12.8	8.90
[2]average individual masse, mg	15.5	17.2	13.7
Note: numerals indicate the corresponding areas.			

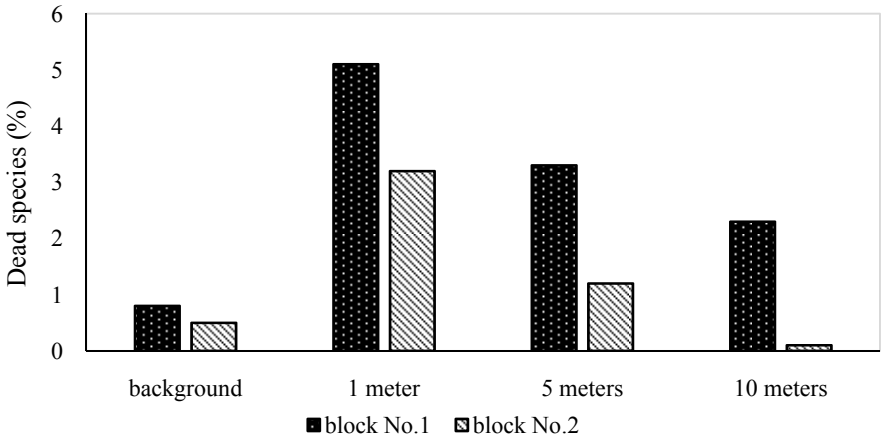


Figure 5 – Change in proportion of dead and/or injured specimens
in the populations of benthic invertebrates at different distances from the pneumatic source

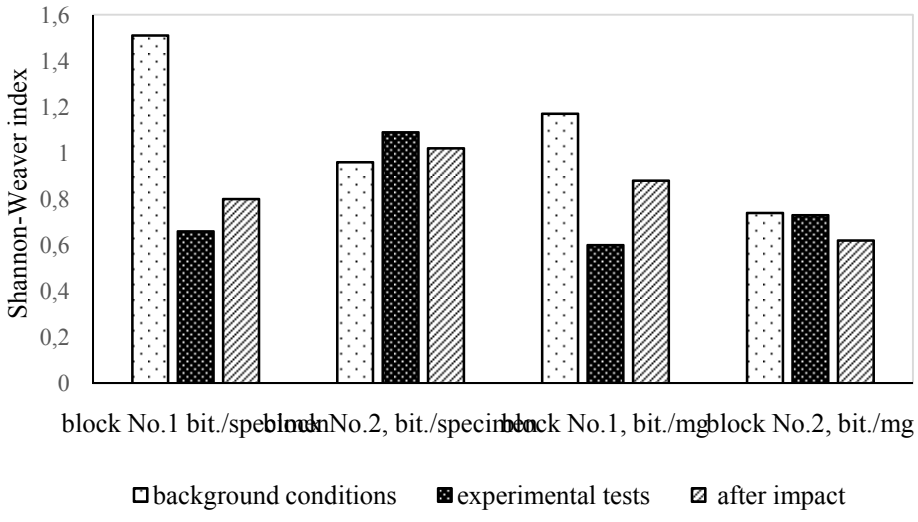
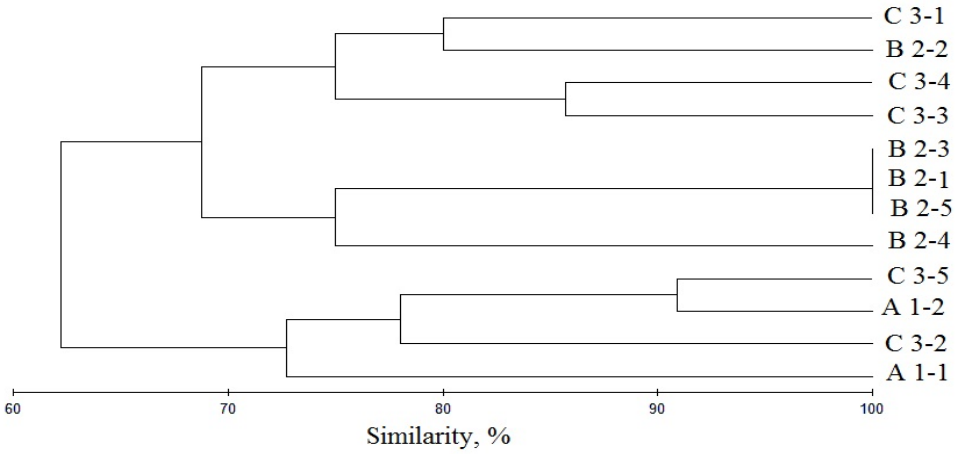


Figure 6 – The dynamics of the Shannon-Weaver index values at different stages of the surveys
of the impact of seismic acoustic zoobenthos

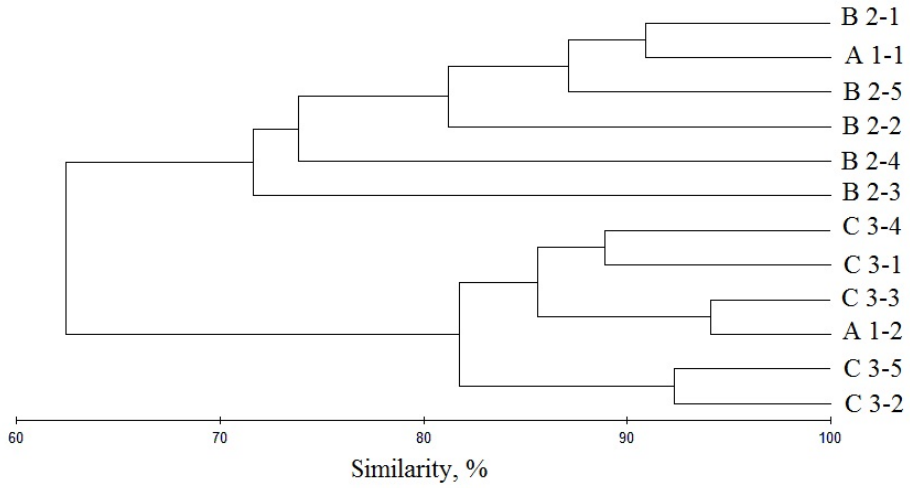
The dynamics of Shannon-Weaver index values across the sites varied irregularly, but in all cases, a deviation of indicator from the background value and from the values obtained during the period after the end of impact was recorded (Figure 6).

Fish fauna was presented by 11-13 bento-pelagic species. The composition of background species include dried fish *(Rutilus rutilus)*, sprat *(Clupeonella cultriventris)*, silverside *(Atherina boyeri caspia)*, steers – *Neogobius melanostomus*, *Mesogobius gymnotrachelus macrophth, Neogobius caspius*. At the same time, species composition of fish fauna had a high degree of similarity throughout all stages of surveys (Figures 7, 8).



A – before impact, B – during impact, C – after impact

Figure 7 – Dendrogram of similarity in species composition of the fish fauna in area No.1



A – before impact, B – during impact, C – after impact

Figure 8 – Dendrogram of similarity in species composition of the fish fauna in area No.2

The number and variety indicators of bento-pelagic ichthyocenosis during the seismic operations at both areas were lower compared to background levels and stages after impact (Table 4). Changes of ichthyocenosis structure during the seismic survey were accompanied by a relative increase of average weight of individual specimen.

The Shannon-Weaver index recorded during seismic surveys was minimal relative to other stages of the surveys (Figure 9).

At the stage of experimental tests, in the populations of bento-pelagic fish species the proportion of traumatized specimens decreased with distance from the pneumatic source (Table 5, Figure 10). On the area No.1, the value of this indicator for all experimental stations was higher by more than 1.5 times, compared to the area No.2.

Table 4 – The structural indicators of fish fauna (bento-pelagic communities) of the Northern Caspian Sea at various surveys stages

Indicator	Background conditions	Experimental tests	After impact
[1]number of species	13	8	10
[2]number of species	8	6	9
[1]average abundance, spec./effort	355	70	312
[2]average abundance, spec./effort	213	112	121
[1]Shannon-Weaver index, bit/spec.	1.8	1.2	1.6
[2]Shannon-Weaver index, bit/spec.	1.45	1.12	1.51
[1]Shannon-Weaver index, bit/mg	1.45	1.13	1.29
[2]Shannon-Weaver index, bit/mg	1.40	0.98	1.41
[1]average individual masse, mg	6.1	6.9	5.6
[2]average individual masse, mg	6.3	7.3	6.9
Note: numerals indicate corresponding areas.			

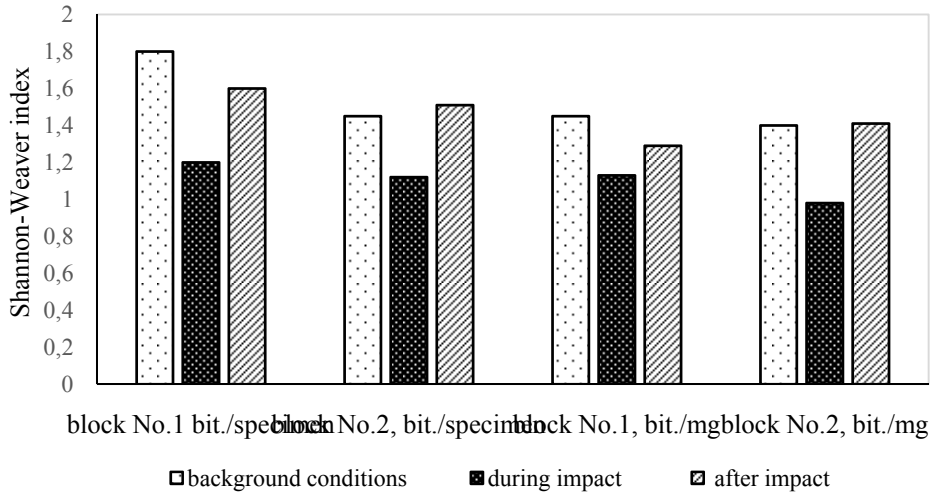


Figure 9 – Dynamics of Shannon-Weaver index values at different stages of surveys on the effects of seismic operations on the fish fauna

Table 5 – Average fish fauna injury during experimental tests

Indicator	Distance from pneumatic source		
	1 meter	5 meters	10 meters
[1]proportion of injured or dead specimens, %	33.3	13.3	0.0
[2]proportion of injured or dead specimens, %	68.4	39.2	10.5
Note: numerals indicate the corresponding areas.			

Thus, our experimental and field studies have shown that, for assessing the impact of seismic operations, the relative indicators – the proportion of injured and/or dead specimens, the values of diversity index of Shannon-Weaver and the size of the average individual weight of specimens in hydrocenoses have the greatest significance to the indicator. The maximum proportion of injured and/or dead specimens in the populations of plankton and benthic invertebrates, as well as the deviation of the values of diversity index of Shannon-Weaver and average individual weight in both communities from background values were recorded during the experimental tests in close proximity to the pneumatic source.

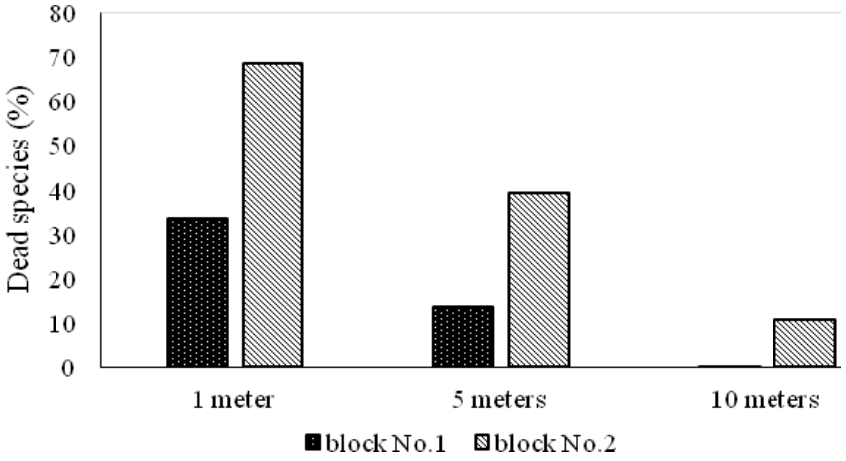


Figure 10 – Change in the proportion of dead specimens
in zoobenthos populations at different distance from the pneumatic source

In the absence of differences in the species composition of fish fauna in various stages of surveys, the minimum diversity and abundance of fish have been observed during the seismic survey. The increase in the average weight of specimens in ichthyocenosis, along with a reduction in numbers during the seismic survey may indicate avoidance of unfavorable zone by younger fishes. This group of aquatic organisms is the most mobile and during the entire seismic surveys can quickly leave the water area with irritating physical influences (noise, vibration, etc.), which is confirmed by the dynamics of structural indicators of ichthyocenoses. Also important the fact that larger specimens that are less susceptible to the effects of seismic acoustic stay in the area of the seismic operations. Similar examples in the behavioral response of fish observed in materials of other experimental studies on assessment of the impact of seismic sources on aquatic organisms [7-9].

Our results enable us to conclude that in conducting seismic surveys, the representatives of bento-pelagic ichthyocenos are subject to an insignificant impact, which is not reflected in terms of their natural life. Planktonic and benthic invertebrates with relatively low levels of mobility are at a significant risk of injury directly in the area affected by pneumatic source.

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В. В. Садомский[1], Е. Г. Крупа[2], И. М. Аминова[3]

[1]"SED" ЖШС, Алматы, Қазақстан,
[2]ҚР БҒМ "Зоология институты" РММ, Алматы, Қазақстан,
[3]"Ақжайық" мемлекеттік табиғи резерваты, Атырау, Қазақстан

СОЛТҮСТІК КАСПИЙ АКВАТОРИЯСЫНДАҒЫ ГИДРОБИОНТТАРДЫҢ СЕЙСМОАКУСТИКАЛЫҚ ӘСЕРІН ЭКСПЕРИМЕНТТІК ЗЕРТТЕУЛЕР

Аннотация. Мақалада 2012–2013 жылдардың жазғы кезеңінде Солтүстік Каспийдің зоопланктонына, макрозообентосына және ихтиофаунасына сейсмоакустикалық әсер етудің эксперименталдық және табиғи зерттеулерінің материалдары ұсынылған. Сейсмобарлау жұмыстарының әсер етуін бағалау үшін жарақат алған немесе өлген дарақтар үлесінің, Шеннон-Уивердің әртүрлілік индексі мәнінің және дарақтың гидроценоздардағы орташа жеке массасының шамасының ең көп индикаторлық маңыздылығы бар екендігі көрсетілген.

Жарақат алған немесе өлген дарақтардың планктонды және сутүбі омыртқасыздар популяцияларындағы максималды үлесі пневмокөзден 1 және 5 м арақашықтықта тәжірибелі сынақтарды жүргізу кезеңінде тіркелген болатын. Бұл кезеңде екі топтануда фондық шамалардан Шеннон-Уивердің әртүрлілік индексі шамаларының және дарақтың орташа жеке массасының ауытқуы байқалды.

Ихтиофаунаның түрлік құрамында зерттеулерді жүргізудің барлық кезеңдерінде жоғары дәрежесі бар болды. Әртүрліліктің минималды көрсеткіштері (түрлердің саны, Шеннон-Уивер индексінің мәні) және балықтардың саны сейсмобарлау жұмыстарын жүргізу кезінде байқалған болатын. Дарақтардың ихтиоценоздардағы орташа жеке массасының көбеюі, сейсмобарлау жұмыстарын жүргізу кезінде санның азаюымен қатар, кіші жастағы балықтардың қолайсыз аймақтардан аулақ болуын куәландыруы мүмкін.

Түйін сөздер: зоопланктон, зообентос, балықтар, пневматикалық соққы көздері, сейсмикалық барлау жұмыстары.

В. В. Садомский[1], Е. Г. Крупа[2], И. М. Аминова[3]

[1]ТОО «SED», Алматы, Казахстан,
[2]РГП на ПХВ «Институт зоологии» КН МОН РК, Алматы, Казахстан,
[3] Государственный природный резерват «Акжайык», Атырау, Казахстан

ЭКСПЕРИМЕНТАЛЬНЫЕ ИССЛЕДОВАНИЯ СЕЙСМОАКУСТИЧЕСКОГО ВОЗДЕЙСТВИЯ НА ГИДРОБИОНТОВ СЕВЕРНОГО КАСПИЯ

Аннотация. Представлены материалы экспериментальных и натурных исследований сейсмоакустического воздействия на зоопланктон, зообентос и ихтиофауну Северного Каспия в летний период 2012–2013 гг. Показано, что для оценки влияния сейсморазведочных работ наибольшую индикаторную значимость имеют доля травмированных или мертвых особей, значения индекса разнообразия Шеннона-Уивера и величины средней индивидуальной массы особи в гидроценозах. Максимальная доля травмированных и/или мертвых особей в популяциях планктонных и донных беспозвоночных была зафиксирована в период проведения опытных испытаний на расстоянии 1 и 5 м от пневмоисточника. В этот же период наблюдалось отклонение значений индекса разнообразия Шеннона-Уивера и средней индивидуальной массы особи в обоих сообществах от фоновых значений. Видовой состав ихтиофауны имел высокую степень сходства на всех этапах проведения исследований. Минимальные показатели разнообразия (число видов, значения индекса Шеннона-Уивера) и численности рыб были отмечены во время проведения сейсморазведочных работ. Увеличение средней индивидуальной массы особи в ихтиоценозах, наряду со снижением численности во время проведения сейсморазведочных работ, может свидетельствовать об избегании рыбами младших возрастов неблагоприятной зоны.

Ключевые слова: зоопланктон, зообентос, ихтиофауна, пневмоисточник, сейсморазведочные работы.

Сведения об авторах:

Садомский Владислав Владимирович – ведущий специалист, магистр, ТОО «SED», лаборатория экологических исследований, vsadomsky@sed.kz

Крупа Елена Григорьевна – главный научный сотрудник, доктор биологических наук, РГП Институт Зоологии КН МОН РК, отдел энтомологии, elena_krupa@mail.ru

Аминова Ирина Менежановна – научный сотрудник-гидробиолог, магистр, Государственный природный резерват «Акжайык», agrimony92@mail.ru

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