

## PECULIARITIES OF DISTRIBUTION OF CARIDEAN SHRIMP LARVAE (DECAPODA, CARIDEA) IN EASTERN PART OF THE SEA OF OKHOTSK

Sedova N.A.<sup>1</sup>, Grigorev S.S.<sup>2</sup>

<sup>1</sup> Kamchatka State Technical University, Petropavlovsk-Kamchatsky, 683003, Russia

<sup>2</sup> Kamchatka Division of Pacific Institute of Geography, Far East Branch, Russian Academy of Sciences, 683000, Russia

Species composition and long-term distribution of shrimp meroplankton in eastern part of Okhotsk Sea are described. Interannual and seasonal variability of qualitative and quantitative composition of shrimp meroplankton is discussed. Average abundance of larvae per station in different areas in spring varied within 1–77.5 ind./m<sup>2</sup>, in first half of summer – 13.1–133 ind./m<sup>2</sup>, in September – 1–27 ind./m<sup>2</sup>. Larvae of genera *Pandalus* and *Eualus* were most abundant in April. In summer larvae of family Crangonidae dominated above shallow waters, and Pandalidae dominated above bottom deeper than 100 m. Maximum abundance (1410 ind./m<sup>2</sup>) was observed in July. Most of larvae develop in upper layer of pelagic zone. In spring larvae were found above bottom depths more than 300 m. In first half of summer main concentrations were above outer and middle shelf, in second half of summer – above inner shelf. Late stages inhabit above bottom depths no more than 40 m.

**Key words:** shrimp, meroplankton, larvae, development, species composition, distribution, abundance, density, western Kamchatka shelf.

### INTRODUCTION

Along Kamchatka coast inhabit 58 species of carid shrimp (infraorder Caridea). Currently, only few species are caught in Kamchatka waters, because commercial reserves of most species have not been explored. Commercial species are pink shrimp *Pandalus eous* Makarov, 1935, humpy shrimp *P. goniurus* Stimpson, 1860, coonstripe shrimp *P. hypsinotus* Brandt, 1851, kuro shrimp *Argis lar* (Owen, 1839), sculptured shrimp *Sclerocrangon boreas* (Phipps, 1774), bering shrimp *S. salebrosa* (Owen, 1839), dokdo shrimp *Lebbeus armatus* (Owen, 1839) [Slizkin, 2006; Marin, 2013]. Expanding fishery requires exploration and study of new stocks of shrimp from poorly studied areas [Kalashnikov, 1984; Koblikov et al., 2002].

Caridean shrimps are animals that form hemipopulations in plankton. Limiting role of environmental factors in shrimps at early stages of development is most pronounced [Konstantinov, 1986]. It is known that early pelagic period of shrimp life affects commercial stock [Pedersen et al., 2002]. Comprehensive study of early stages of development of shrimps is necessary to determine stability of ecosystem, especially in condition of climate change at high latitudes.

Shrimps well known as dominant component of epibenthic community due to their high abundance, density and biomass. They sometimes form up to 60–80% of biomass in shallow coastal waters, especially on sandy bottom without algae [Evans, Tallmark, 1985; Hostens, Hamerlynck, 1994; Hostens, 2000; Lapinska and Szaniawska, 2006; Neves et al.,

2007; Campos, Van der Veer, 2008]. Almost all developmental stages of shrimp are food for many pelagic and benthic fish. In addition, crustaceans themselves have significant impact on populations of commercial fish, eating their eggs and larvae, as well as juveniles of settling flounders [Edwards, Steele, 1968; Gibson et al., 1985; Van der Veer and Bergman, 1987; Modin, Pihl, 1996; Wennhage, Gibson, 1998]. Consequently, shrimp can act as structuring force in shallow benthic communities [Evans, 1984; Reise, 1985; Mattila et al., 1990]. Comprehensive study of larval development of shrimp is necessary for protection and management of both their resources and the resources of other commercial aquatic organisms.

There is scarce data on distribution of shrimp larvae in seas of Russian Far East. Shrimp larvae of three families (Crangonidae, Pandalidae and Thoridae) are regularly found in plankton samples taken in eastern part of Okhotsk Sea. Larvae of many shrimps, especially of family Thoridae, not described. Development of larvae with shortened development has been least studied.

Aim of this study was to understand regularities of spatial distribution of caridean shrimp larvae in eastern part of Okhotsk Sea near western coast of Kamchatka peninsula, to characterize interannual and seasonal variability of qualitative and quantitative composition of shrimp meroplankton.

## MATERIALS AND METHODS

Materials for this study were plankton samples collected according to Kamchatka Research Institute of Fisheries and Oceanography (KamchatNIRO) scientific program in eastern part of Okhotsk Sea during period from 1999 to 2016. A total of 1151 samples were analyzed (Fig. 1, Table 1).

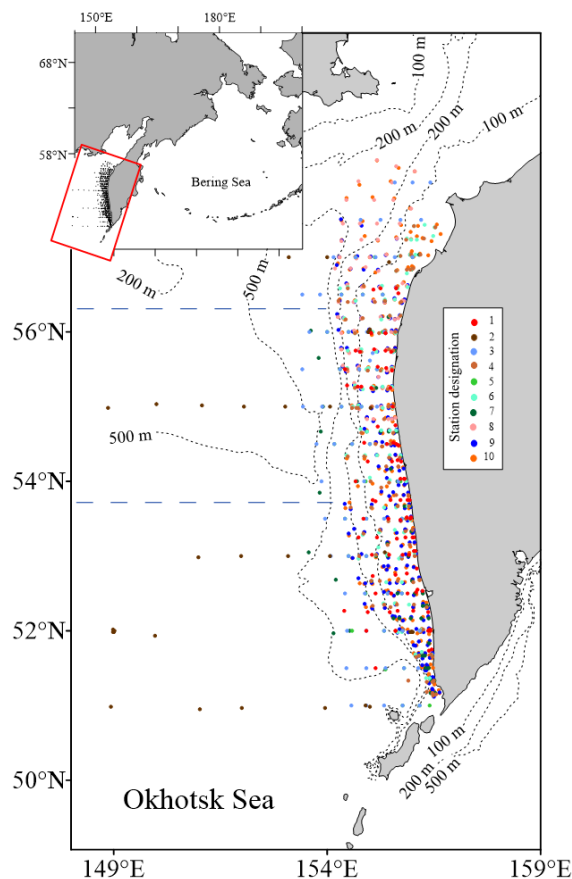


Fig. 1. Scheme of plankton stations in eastern part of Okhotsk Sea carried out from 1999 to 2016. Dashed line shows division of area into northern, central and southern parts. Designations: 1 – 15 July–19 August 1999, 2 – 6–30 September 1999, 3 – 9–29 April 2001, 4 – 2 July–5 August 2001, 5 – 22–29 April 2002, 6 – 15 July–12 August 2002, 7 – 3 September – 10 October 2003, 8 – 31 July–11 August 2013, 9 – 6 June–2 July 2015, 10 – 2 June–2 July 2016

Samples were fixed in 4% formalin and bring to onshore laboratory. In each sample taxonomic composition of larvae and stages of their development, as well as number of larvae, were determined.

This study used hydrological materials of cruise reports received in the corresponding period (KamchatNIRO archive). Hydrological observations were carried out at plankton stations using ASTD-102 RINKO sounding complex (JFE, Japan). Measurements of temperature, pressure (bottom depth), electrical conductivity (salinity) were performed at intervals of 0.5 m of depth in entire plankton collection layer.

Table 1. Stations, dates, depths, numbers of samples analyzed and shrimp larvae caught for this study

| Date                          | Bottom depths, m | Samples analyzed | Samples with larvae | Larvae caught, ind. |
|-------------------------------|------------------|------------------|---------------------|---------------------|
| 15 July – 19 August 1999      | 15–300           | 85               | 68                  | 910                 |
| 6–30 September 1999           | 26–1450          | 41               | 7                   | 10                  |
| 9–29 April 2001               | 30–850           | 69               | 18                  | 58                  |
| 2 July – 5 August 2001        | 15–210           | 107              | 79                  | 1471                |
| 22–29 April 2002              | 30–739           | 36               | 14                  | 48                  |
| 15 July – 12 August 2002      | 15–200           | 93               | 47                  | 831                 |
| 3 September – 10 October 2003 | 15–845           | 74               | 27                  | 219                 |
| 31 July – 11 August 2013      | 12–568           | 84               | 30                  | 216                 |
| 6 June – 2 July 2015          | 15–559           | 247              | 117                 | 5108                |
| 2 June – 2 July 2016          | 15–569           | 246              | 72                  | 653                 |

The systematic position of species is determined taking into account modern databases (The World Register of Marine Species, Arcticmegabenthos, MarBEF Data System). To identify species of shrimp larvae we used guides and keys for Kamchatka marine waters [Sedova, Grigoriev, 2016, 2017a, 2017b; Sedova, 2019] and articles describing larvae of certain species [Ivanov, 1965, 1971; Makarov, 1966, 1967; Haynes, 1980, 1981, 1985; Squires, 1993; Sedova, Grigoriev, 2014, 2015; 2017c, 2018].

Catches of shrimp larvae were indicated in specimens per m<sup>2</sup> of sea surface. Due to small catches of larvae, their horizontal distribution in maps is given in averaged data for entire study period in the eastern part of Okhotsk Sea, implemented in period from 1999 to 2018. For convenience of presentation, entire study area was divided into three parts: northern (north of 56.2°N), central (53.7–56.2°N) and southern (south of 53.7°N). These boundaries are drawn similarly to the areas of averaging of data adopted in plankton and crab studies [Slizkin et al., 2001]. All samples were analyzed and species identified by N. Sedova.

## RESULTS

### *Species composition, abundance and general distribution of shrimp larvae*

In samples collected in eastern part of the Okhotsk Sea, shrimp larvae of more than

40 species belonging to three families: Crangonidae, Pandalidae, and Thoridae, were found (Table 2). Most of them are Pacific widespread boreal sublittoral or sublittoral-bathyal species. Species *Eualus suckleyi* (Stimpson, 1864), *E. belcheri* (Bell, 1855), *Lebbeus armatus* (Owen, 1839), *Neocrangon communis* Rathbun, 1899, *Pandalus goniurus* Stimpson, 1860, *Spirontocaris arcuata* Rathbun, 1902, and *S. intermedia* Makarov and Kobjakova, 1936 are arctic-boreal. Species *E. pusiolus* (Kröyer, 1841), *E. macilentus* (Kröyer, 1842), and *S. phippii* (Kröyer, 1841) distributed circumpolarly. *Argis dentata* (Rathbun, 1902) – amphiboreal species.

Shrimp larvae were found in samples from March to October. In April most abundant were *P. eous* Makarov, 1935 and representatives of genus *Eualus*. In summer above shallow depths prevailed in numbers larvae of species *N. communis*, *Crangon dalli* Rathbun, 1902, and *C. septemspinosa* Say, 1818, and above bottom depths over 100 m prevailed *P. eous* and *P. goniurus*. In autumn prevailed *C. dalli*, *C. septemspinosa*, and *Eualus spp.* In spring larvae were more abundant in southern part, in summer and autumn occurrence was approximately equal in all areas. General distribution of shrimp larvae of all species for entire study period by season is shown in Fig. 2. Distribution of larvae of commercial shrimp species is given separately (Fig. 3).

Table 2. List of species of shrimp larvae in eastern part of Okhotsk Sea examined in this study, including bottom depth, maximal abundance, and zoeal stages. Designations: dec – decapodid stage, 0 – larvae not found, dash – no data

| Species, taxons               | April – May     |                                  |              | June – August   |                                  |              | September – October |                                  |              |
|-------------------------------|-----------------|----------------------------------|--------------|-----------------|----------------------------------|--------------|---------------------|----------------------------------|--------------|
|                               | Bottom depth, m | Max. abund., ind./m <sup>2</sup> | Zoeal stages | Bottom depth, m | Max. abund., ind./m <sup>2</sup> | Zoeal stages | Bottom depth, m     | Max. abund., ind./m <sup>2</sup> | Zoeal stages |
| <b>Pandalidae</b>             |                 |                                  |              |                 |                                  |              |                     |                                  |              |
| <i>Pandalus eous</i>          | 300–350         | 20                               | I            | 11–307          | 110                              | I–VIII       | 58                  | 2                                | VII          |
| <i>P. goniurus</i>            | 550             | 2                                | I            | 11–145          | 316                              | I–VII        | –                   | 0                                | –            |
| <i>P. hypsinotus</i>          | –               | 0                                | –            | 26–106          | 2                                | V            | –                   | 0                                | –            |
| <i>P. tridens</i>             | –               | 0                                | –            | 21–154          | 8                                | I–III        | –                   | 0                                | –            |
| <b>Crangonidae</b>            |                 |                                  |              |                 |                                  |              |                     |                                  |              |
| <i>Crangon septemspinosus</i> | –               | 0                                | –            | 15–50           | 78                               | I,II,V       | 15                  | 34                               | II–V         |
| <i>C. dalli</i>               | –               | 0                                | –            | 5–32            | 1118                             | I,II,V       | 50–120              | 46                               | I–dec        |
| <i>Mesocrangon intermedia</i> | –               | 0                                | –            | 5–91            | 600                              | I–V, dec     | –                   | 0                                | –            |
| <i>Neocrangon communis</i>    | –               | 0                                | –            | 5–91            | 402                              | I–V, dec     | 50–120              | 52                               | I–dec        |
| <i>Rhynocrangon sp.</i>       | 300–850         | 6                                | I            | 145             | 2                                | II           | –                   | 0                                | –            |
| <i>Argis crassa</i>           | –               | 0                                | –            | 30.5–80         | 4                                | I,II         | –                   | 0                                | –            |
| <i>A. lar</i>                 | –               | 0                                | –            | 15–80           | 4                                | II–III       | –                   | 0                                | –            |
| <i>A. ovifer</i>              | –               | 0                                | –            | 20–27           | 2                                | II           | –                   | 0                                | –            |
| <i>A. dentata</i>             | –               | 0                                | –            | 30–58           | 2                                | I,II         | –                   | 0                                | –            |
| <b>Thoridae</b>               |                 |                                  |              |                 |                                  |              |                     |                                  |              |
| <i>Spirontocaris phippii</i>  | –               | 0                                | –            | 16–100          | 6                                | III–V        | –                   | 0                                | –            |
| <i>S. ochotensis</i>          | –               | 0                                | –            | 18–25           | 14                               | IV           | –                   | 0                                | –            |
| <i>Eualus fabricii</i>        | –               | 0                                | –            | 11–41           | 4                                | III,IV       | –                   | 0                                | –            |
| <i>E. belcheri</i>            | –               | –                                | –            | 31–79           | 10                               | II–III       | –                   | –                                | –            |
| <i>E. barbatus</i>            | 350–850         | 10                               | I            | –               | –                                | –            | –                   | –                                | –            |
| <i>E. macilentus</i>          | –               | –                                | –            | 40              | 40                               | I            | –                   | –                                | –            |
| <i>E. spp.</i>                | 300–850         | 16                               | I–IV         | 10–348          | 842                              | I–V, dec     | –                   | 0                                | –            |
| <i>Birulia sp.</i>            | –               | 0                                | –            | 18–31           | 4                                | II, III      | –                   | 0                                | –            |
| <i>Lebbeus armatus</i>        | –               | 0                                | –            | 358             | 2                                | II           | –                   | 0                                | –            |

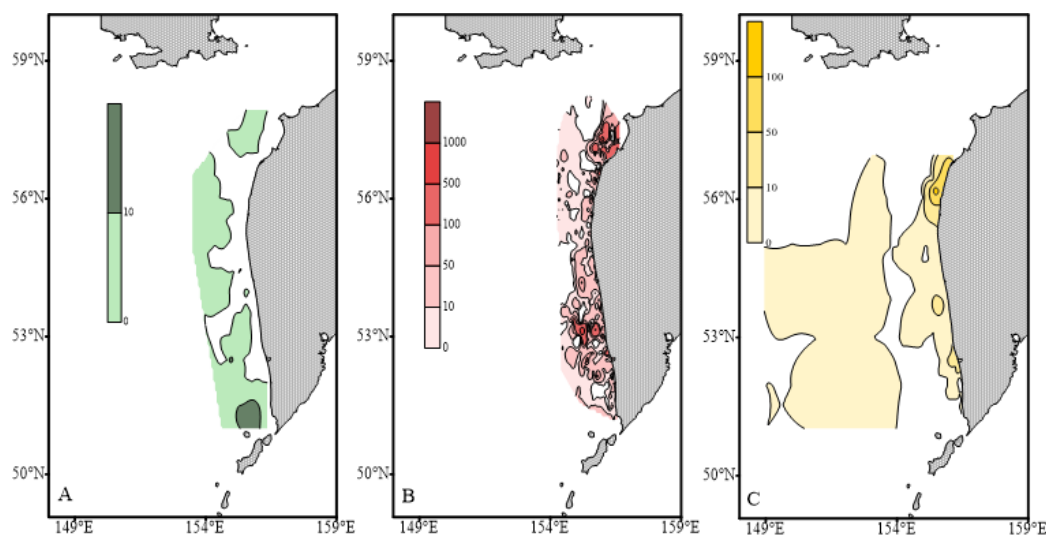


Fig. 2. Generalized distribution of shrimp larvae of all species during entire study period from 1999 to 2016 by seasons: A – spring, B – summer, C – fall. Legend: numbers of larvae per m<sup>2</sup>

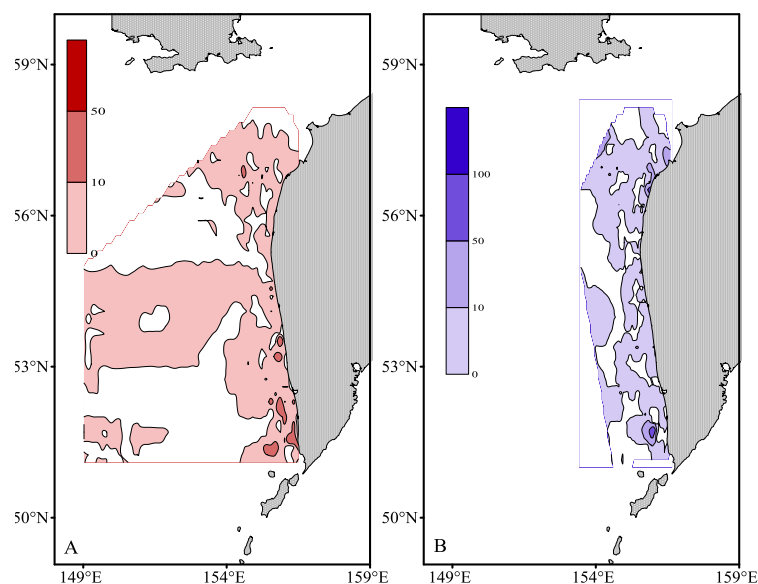


Fig. 3. Generalized distribution of larvae of commercial shrimp species during entire study period from 1999 to 2016 (all seasons): A – *Pandalus eous*, B – *Pandalus goniurus*. Legend: numbers of larvae per m<sup>2</sup>

Larvae of family Crangonidae of species *Crangon septemspinosa*, *C. dalli*, *Neocrangon communis*, and *Mesocrangon intermedia* were widespread and abundant (Fig. 4).

Shrimp larvae of species *Pandalus hypsinotus* and *P. tridens* (family Pandalidae), *Eualus fabricii*, *E. belcheri*, *Spirontocaris phipsi*, *S. ochotensis*, and *Lebbeus armatus* (family Thoridae), *Argis crassa*, *A. dentata*, *A. lar*, and *A. ovifer* (family Crangonidae) were rarely found in samples. Places of capture of rare shrimp larvae are shown in Fig. 5.

Shrimp larvae were found above bottom depths of 9 to 800 m throughout entire of the study area. In April, larvae were caught beyond western Kamchatka shelf. Abundance of larvae in spring and in second half of summer in southern part was, as a rule, higher than in central and northern parts of study area. Exception was extremely cold 2001 [Luchin, Matveyev, 2016], when in north average abundance was slightly higher (Table 3). In summer, larvae were caught closer to coast, over middle and inner shelf. In first half of summer, in warmest 2015, largest number of larvae was in north (average abundance 70.9 ind./m<sup>2</sup>). In autumn, no larvae were

found above depths of more than 200 m. In September most of them were concentrated over bottom depth of 30–50 m.

In March – April larvae were caught over high depths far from coast. In the extremely cold 2001, the larvae were recorded exclusively outside the shelf, above depths of more than 300 m. In spring, larvae were found in samples regularly (in 57.6% of all samples), but in small numbers. In temperate 2002, single larvae of *P. eous* were observed in northern part above bottom depths 50–80 m. Early larvae of *P. eous* and *Eualus spp.* were caught in 70% of samples in central and southern parts of study area above bottom depth 100–200 m. Larvae of these species were present in 83.8% of samples collected over bottom depth of more than 200 m (Table 4).

Shrimp larvae were found above all bottom depths in first half of summer. In June 2015 main stock of larvae concentrated over depth of 50–150 m (occurrence in samples 33–85.7%). In 2016 occurrence was somewhat lower than in warm years. Larvae of coastal crangonids and thorids (genera *Argis*, *Spirontocaris*) were caught close to coast.

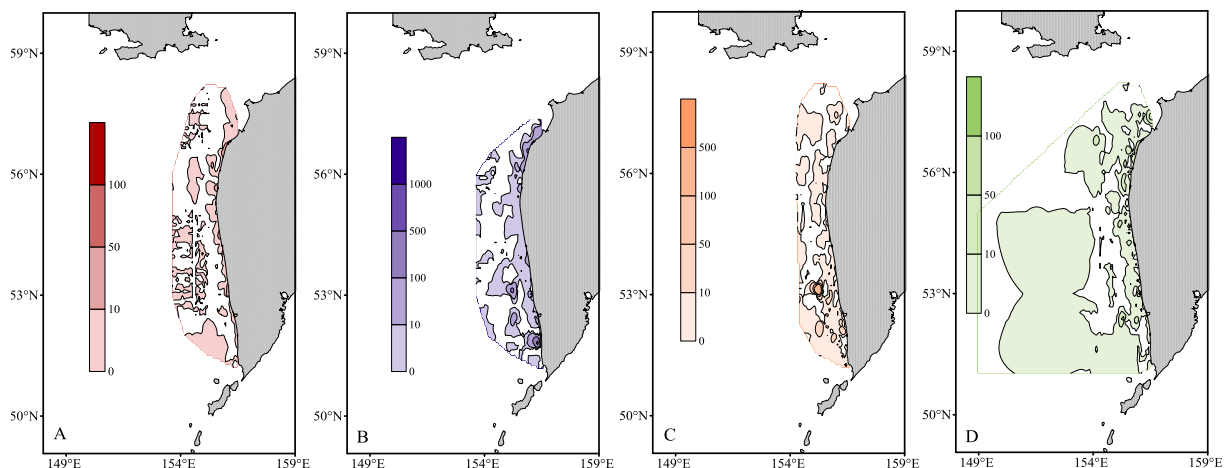


Fig. 4. Generalized distribution of abundant larvae of family Crangonidae during entire study period from 1999 to 2016 (all seasons): A – *Crangon septemspinosus*, B – *Crangon dalli*, C – *Neocrangon communis*, D – *Mesocrangon intermedia*. Legend: numbers of larvae per m<sup>2</sup>. Maximum catches were only in single stations, therefore they were not signify in distribution schemes

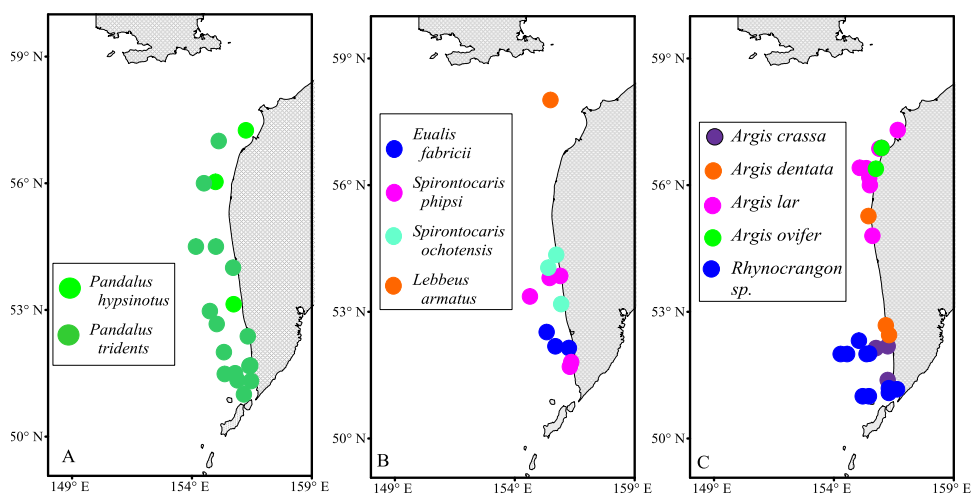


Fig. 5. Locations of rare shrimp larvae of families Pandalidae (A), Crangonidae (B), and Thoridae (C) during entire study period from 1999 to 2016 (all seasons)

Table 3. Average numbers of shrimp larvae in eastern part of Okhotsk Sea, numbers of larvae per m<sup>2</sup>

| Month of survey     | Year of survey | Conditional parts of western Kamchatka shelf |         |       |
|---------------------|----------------|--|---------|-------|
|                     |                | North  | Central | South |
| April               | 2001           | 1.0  | 3.0     | 7.5   |
|                     | 2002           | 1.2  | 3.3     | 8.4   |
| June – July         | 2014           | 2.7  | 2.8     | 0     |
|                     | 2015           | 70.9   | 12.5    | 29.9  |
|                     | 2016           | 25.1   | 7.0     | 20.6  |
| July – August       | 1999           | 45.7   | 42.3    | 85.1  |
|                     | 2001           | 45.7   | 32.9    | 30.5  |
|                     | 2002           | 53.6   | 15      | 133.0 |
|                     | 2013           | 13.1   | 16.5    | 0     |
| September           | 1999           | 10.0   | 0       | 4.0   |
| September – October | 2003           | 27.0   | 18.8    | 12.0  |

Table 4. Occurrence of shrimp larvae in samples (% of total number of samples)

| Month of survey | Year of survey | Conditional parts of western Kamchatka shelf |         |       |
|-----------------|----------------|--|---------|-------|
|                 |                | North  | Central | South |
| April           | 2001           | 2.9  | 25.0    | 42.9  |
|                 | 2002           | 2.0  | 27.3    | 55.6  |
| June – July     | 2014           | 68.0   | 75.0    | 0     |
|                 | 2015           | 57.1   | 67.2    | 77.4  |
|                 | 2016           | 40.0   | 23.5    | 25.6  |
| July – August   | 1999           | 100  | 71.4    | 17.4  |
|                 | 2001           | 19.4   | 62.1    | 53.1  |
|                 | 2002           | 36.0   | 56.8    | 50.0  |
|                 | 2013           | 60.0   | 48.4    | 0     |
|                 | 1999           | 43.0   | 0       | 15.4  |
| September       | 2003           | 100.0  | 50.0    | 48.0  |

### *Distribution of shrimp larvae in spring*

In spring samples were collected in April 2001 and 2002. Shrimp larvae were found beyond shelf above bottom depths up to 400 m in both northern and southern parts of study area. Most of them were zoeae of *Eualus spp.* (their density not exceed 22 ind./m<sup>2</sup>). Besides *Eualus spp.*, single zoeae *P. eous*, *P. goniurus*, and *Rhynocrangon sp.* were caught. All larvae were in their early zoeal stages. In April, the largest accumulations were observed in southern part of study area (above bottom depths 500–800 m) and slightly less in north – above bottom depths higher than 300 m.

In north and south of study area along western Kamchatka larvae in similar stages of development were caught in different distances from coast and above different bottom depths. This fact can be explained by complex system of currents and existence of water circulations over western Kamchatka shelf.

Conditional regions of study differed somewhat in species composition of larvae. In northern part only 2 species were found: *P. eous* and *Eualus sp.* In 2001 zoeae I–II of *Eualus sp.* were caught in 5.9% of all samples with density no more than 8 ind./m<sup>2</sup>. In 2002 only one larva *P. eous* was caught.

In April in central part of study region singly larvae were caught and they were found

in 25% of samples. Few larvae of *P. eous* and *P. goniurus* were caught above bottom depths 300–350 m. In 2002 above bottom depths 125–405 m, species of genus *Eualus* were often caught, which accounted for about 60% of all larvae caught at that time. Remaining 40% were larvae of *P. eous* zoeal stages I–II.

In April in southern part of study region larvae were found in about half of samples. In 2001 dominant species of genus *Eualus*, which accounted for 80% of the number. In 2001 unidentified species of genus *Eualus* dominated, which accounted for 80% of all number. These species formed small aggregations (up to 22 ind./m<sup>2</sup>) above bottom depth 600–700 m. Occurrence was slightly higher in warmer 2002, and zoea I of *P. eous* were 83.3% of all larvae. Density of larvae above bottom depths 236–630 m was no more than 20 ind./m<sup>2</sup>. Most of larvae were caught above maximum bottom depths.

### *Distribution of shrimp larvae in early summer*

In June and July 2015 and 2016 larvae of three families were caught: Pandalidae, Thoridae, and Crangonidae. Larvae of 4 species of family Pandalidae were found: *Pandalus eous*, *P. goniurus*, *P. hypsinotus* Brandt, 1851, *P. tridens* Rathbun, 1902.

The most abundant larvae were *P. goniurus*, which were present in 64.5% of all samples where larvae of this family were found in that period. Larvae of *P. eous* composed 34.4% of all pandalids. Larvae of *P. hypsinotus* and *P. tridens* were appeared in samples sporadically. Zoea of these species were found above bottom depths of 15 to 458 m throughout entire study area.

Family Thoridae was represented by multiple species of two genera: *Spirontocaris* and *Eualus*. These larvae were caught above bottom depths of 14 to 430 m throughout entire study area. Most abundant were larvae of genus *Eualus*, which were found in 63.0% of all samples, where thorids occur. Representatives of genus *Spirontocaris* were found, respectively, in 43.6% of samples family Thoridae.

Larvae of different zoeal stages of 7 species of family Crangonidae were caught: *Argis crassa* (Rathbun, 1899), *Argis lar* (Owen, 1839), *Argis ovifer* (Rathbun, 1902), *Crangon dalli*, *Mesocrangon intermedia*, *Neocrangon communis*, *Rhynocrangon sp.* These larvae were caught above bottom depths of 11 to 430 m throughout study area. Most abundant were zoea of *N. communis*, which occurs in 56.6% of all samples with crangonids. *M. intermedia* was found slightly less frequently – in 34.7% of samples, respectively. Larvae of *A. crassa*, *A. lar*, *A. ovifer*, and *Rhynocrangon sp.* appeared sporadically in samples

Dominated by abundance were: in northern part of study area: *P. goniurus* and *Eualus spp.*, in central part *P. eous*, *P. goniurus*, *Eualus spp.*, and *M. intermedia*, in southern part *P. eous*, *C. dalli*, *N. communis*, and *Eualus spp.*

Larvae of most species of larvae (80.2% of all samples in early summer) were observed mainly above bottom depths from 14 to 100 m. Largest abundance was in north of study area. Numbers of larvae, as a rule, were no more than 60 larvae per m<sup>2</sup>. In some cases accumulations of *N. communis*, *P. goniurus*, and *Eualus spp.* were observed

up to 180 ind./m<sup>2</sup>. When moving from coast, starting from a 30-meter depth, number of larvae increased sharply, and when it reached depth of 100 m, it declined noticeably.

Shrimp larvae were found in 80.2% of all samples above depths of 14 to 458 m throughout the entire study area. Maximum concentrations in one station, formed due to large number of *Eualus spp.* (1410 ind./m<sup>2</sup>) were found in 2015 in beginning of July above bottom depth 40 m in northern part of study area. Accumulation of larvae of *C. dalli* (1124 ind./m<sup>2</sup>) was observed in mid-July above bottom depth of 15 m in southern part. Larvae of *Eualus spp.* formed maximum accumulation (106 ind./m<sup>2</sup>) over bottom depth of 40 m in central part. Larvae of families Crangonidae and Thoridae formed largest aggregations in northern part of study area.

Compared to 2015, in 2016 number of shrimp larvae was lower throughout study area (Fig. 6). Maximum aggregations (up to 158 ind./m<sup>2</sup>) were found in northern and southern parts above bottom depth of 60–72 m due to *P. goniurus*, whose larvae were especially abundant in samples in this year. In northern part average density of all larval species did not exceed 22 ind./m<sup>2</sup>. In north larvae of the current carry them further from the coast, where they met to a depth of 464 m. In north, larvae drifted further from coast, where occur to bottom depth of 464 m.

Larvae of *P. eous* were caught along entire western coast of Kamchatka above bottom depths of 200–500 m. Much abundance (68 ind./m<sup>2</sup>) was recorded near southwestern coast close to 200-m isobath.

#### ***Distribution of shrimp larvae in late summer***

Larvae of *P. eous*, *P. goniurus*, *C. dalli*, *C. septemspinosa*, *N. communis*, *M. intermedia*, and *Eualus spp.* appeared regularly in samples in second half of summer. Larvae of species of

family Crangonidae were most abundant. Larvae at all stages of development were found. Zoeal stages I and II were observed more frequently.

In July – August in northern part of western Kamchatka shelf larvae of *N. communis* dominated. However in some years (2002 and 2013) *Eualus spp.*, *M. intermedia*, *C. dalli*, and *P. goniurus* dominated. In 1999 large concentrations of larvae were not found (maximum was 78 ind./m<sup>2</sup> over bottom depth of 32 m). Mass accumulation of larvae of *C. dalli* and *N. communis* (up to 436 ind./m<sup>2</sup>) was observed in 2001 over bottom depth of 30 m. In 2002 3 species: *C. dalli*, *C. septemspinosa*, and *M. intermedia* formed two large clusters of larvae (over 1000 ind./m<sup>2</sup> of sum of these species). No significant accumulations of larvae were found in 2013.

**Distribution of shrimp larvae in fall**

In September most larvae were found above depths less than 50 m. Above bottom

depths higher than 50 m few larvae were found. In 1999, only late larvae were caught, and in 2003 earlier zoeal stages were found too. All larvae caught in September were mainly in last stages of development. In 1999 plankton was caught mainly above bottom depths of more than 100 m; therefore larvae were found much less than in 2003. In northern part larvae of *P. eous*, *M. intermedia*, *N. communis*, *Eualus spp.*, and *C. dalli* were found. In 1999 above bottom depth 68 m, about 40% of all species in samples were species of genus *Eualus* (up to 20 ind./m<sup>2</sup>).

In 1999 no larvae were found in central part of study area. In 2003 over bottom depth 40 m abundance of 124 ind./m<sup>2</sup> was observed, consisting of larvae of three species: *C. dalli*, *C. septemspinosa*, and *N. communis*. Larvae of *C. dalli* dominated in south of study area. Larvae of this species of all zoeal stages formed small aggregations (up to 46 ind./m<sup>2</sup>) over shallow water. In 1999 only single larvae of *C. septemspinosa* and *N. communis* were caught.

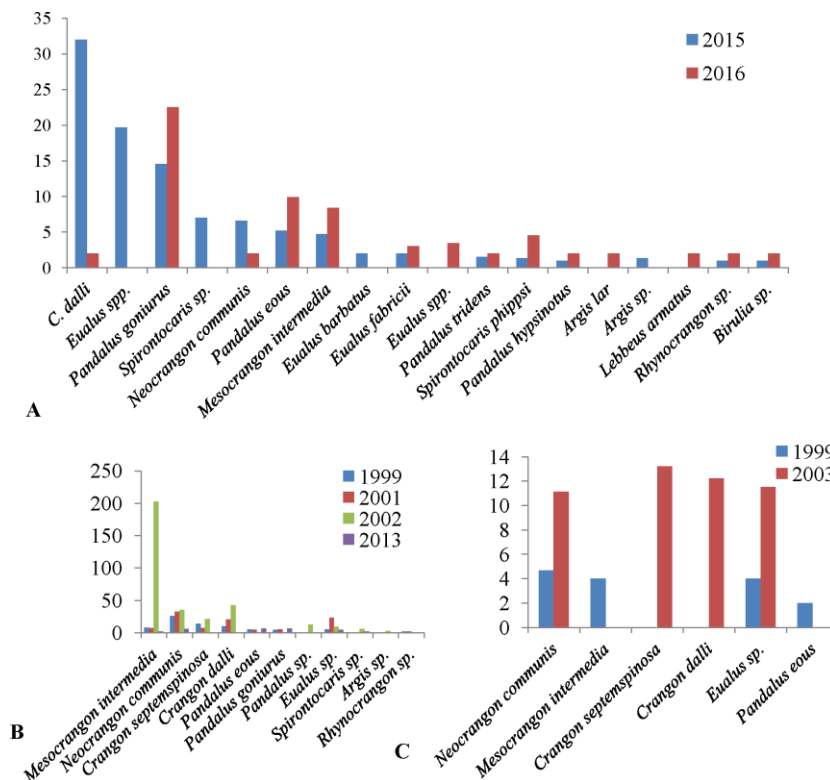


Fig. 6. Average density of caridean shrimp larvae in eastern part of Okhotsk Sea in June 2015 and 2016 (A), in July-August 1999, 2001, 2002, and 2013 (B) and in September 1999, and 2003 (C). Vertically: numbers of larvae per m<sup>2</sup>

## DISCUSSION

Analyzed samples contained shrimp larvae at different stages of development. Four species (*P. eous*, *P. goniurus*, *M. intermedia*, and *N. communis*) were represented in almost all stages of development, but late zoeal stages were most often found. Two species (*Rhynocrangon sp.* and *P. tridens*) were represented only by earliest zoea. Species of genus *Argis* were represented only by latest larvae. Development of these species is short, and therefore, in June-July their larval development completed. Larvae of *M. intermedia*, *N. communis*, *P. goniurus*, *P. eous*, and *Spirontocaris spp.* were most widespread. Maximum larval abundance was observed in northern stations due to accumulations of *N. communis* and complex species of genus *Eualus*. Species diversity in northern part was less, because *P. tridens*, *C. dalli*, *A. crassa*, *A. lar*, *A. ovifer*, and *Rhynocrangon sp.* were absent in that area. Our data on distribution of larvae of *P. eous* in latitudes and depths corresponding to data of Mikhailova [2014] for adults.

In central part of study area zoeae of *N. communis* were most abundant in cold years, in temperate years *C. dalli* and *C. septemspinosa* (in 2002) or *P. goniurus* (in 2013) were most abundant. In 1999 and 2001 maximum accumulations of *N. communis* (530 and 200 ind./m<sup>2</sup>) were found over bottom depths of 20 and 50 m, respectively. In 2002 zoea of *M. intermedia* up to 700 ind./m<sup>2</sup> were caught above bottom depth 15 m. In 2013 no significant accumulations of larvae were found.

In southern part of study area zoea of *N. communis* were also abundant. In addition, there *P. goniurus* were abundant in cold years, and *C. dalli* and *C. septemspinosa* in temperate years. In 1999, one significant aggregation of larvae of *C. septemspinosa*

was found over bottom depth of 15 m. In 2001 larvae of *Eualus spp.* formed accumulation (400 ind./m<sup>2</sup>) over bottom depth of 15 m.

Autumn collections were poor. Almost all larvae were caught in night time. Only exceptions were two specimens of V zoeal stage of *N. communis* caught during daytime. It is known that larvae of this species in late stages inhabit in bottom layers of pelagic zone, and only at night rise to surface [Ouellet, Allard, 2006; Armstrong et al., 1981; Criales, McGowan, 1994]. Scarcity of collections during this period was also due to grid of stations was more sparse, plankton was caught only in upper layers. In addition, in autumn larval development of most shrimp species was already been completed.

In September, in cold years larvae were caught above bottom depths no more than 80 m. Few pandalid larvae were caught farther from coast in warmer years. Most of larvae were caught in coastal waters. Shrimp larvae were found in 20% of samples above bottom depth of 101–200 m.

Distribution of shrimp larvae above bottom depths depends on water temperature and season. In spring larvae hatch into plankton, usually above ocean depths, and by autumn they migrate to shallow water. In cold years in eastern part of Okhotsk Sea in spring larvae were caught exclusively above bottom depths of more than 200 m, in moderate years – above of more than 100 m, i.e. closer to shore (Table 5). In first half of summer larvae were more abundant above depths less than 200 m. In temperate years larvae were most often caught above shallow depths (up to 50 m), less often – above bottom depth 50–100 m. In second half of summer, in cold and temperate years, most of larvae were caught above bottom depth less than 100 m.

In September most of shrimp larvae were caught above bottom depth less than 50 m. In autumn larvae were absent outside shelf.

In second half of summer similar picture was observed: in cold years there were practically no larvae outside shelf, but in temperate years they were present in small numbers in third of samples taken above these depths. In July-August above bottom depths of 100–200 m in cold years larvae were caught only in southern part, and in temperate years, in all parts of study area. In spring larvae develop above high depths, and in summer main stock of larvae in eastern part of Okhotsk Sea was concentrated above depths of 70–100 m. In September almost all larvae were concentrated over bottom depths less than 50 m. Thus, so-called "larval belt" is formed in different seasons over different bottom depths (Fig. 7).

## CONCLUSIONS

In spring, larvae were present in 2–55.6% of samples, in first half of summer – in 23.5–67.2%, in second half of summer in 17.4–100% of samples, in September – from 15.4 to 100% all analyzed samples of corresponding period. Mass development of larvae occurs, as a rule, from May to August, but in some years timing may shift. Maximum duration of development was observed for species that hatch in spring over high bottom depths. In the same species late larvae develop 1.5–2 times faster than early ones.

Table 5. Frequency of occurrence of caridean shrimp larvae above different bottom depths in eastern part of Okhotsk Sea (% of samples) depending on temperature type of years. Dash indicates no data

| Month       | Year type<br>(after Luchin & Matveyev, 2016) | Vertical distribution of larvae |             |           |                   |
|-------------|--|---------------------------------|-------------|-----------|-------------------|
|             |  | Above 50 m                      | Above 100 m | 101–200 m | Deeper than 200 m |
| April       | Cold   | –                               | 0           | 0         | 57.6              |
|             | Temperate                                    | –                               | 2.0         | 50.0      | 83.8              |
| June-July   | Temperate                                    | 87.5                            | 50.0        | 49.3      | 30.0              |
|             | Warm   | 75.0                            | 76.9        | 62.8      | 47.1              |
| July-august | Cold   | 92.9                            | 85.8        | 2.2–60.2  | 1.2               |
|             | Temperate                                    | 74.4                            | 50.0        | 0–59.2    | 14.0              |
| September   | Cold   | –                               | 33.3        | 2.1       | 0.5               |
|             | Temperate                                    | 71.9                            | 12.0        | 20.0      | 0                 |

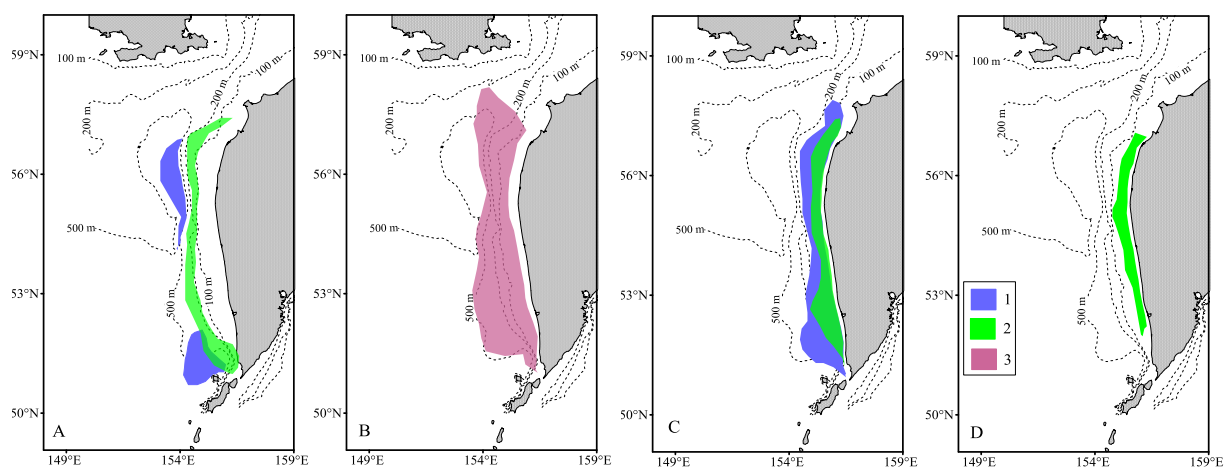


Fig. 7. Scheme of the larval belt above western Kamchatka shelf in cold years (1), moderate years (2), and warm years (3). A – April, B – June, C – July, D – September

Larval development occurs mainly over middle and inner shelf. Abundance of larvae varies over different bottom depths. Maximum concentrations of shrimp larvae over Western Kamchatka shelf were about 500 ind./m<sup>2</sup>. Larvae of species of family Crangonidae prevailed. Maximum concentration of shrimp larvae (1410 ind./m<sup>2</sup>) was found in 2015 in early July in northern part of study area. Average abundance of larvae in one station varied in spring within 1–8.4 ind./m<sup>2</sup>, in first half of summer – 2.7–70.9 ind./m<sup>2</sup>, in second half of summer – 13.1–133, in September – from 0 to 27 ind./m<sup>2</sup>.

As development progresses, larvae begin gradually migrate to coast, using compensatory sea currents or moving along large gyres. In first half of summer, lot of shrimp meroplankton appears first in outer zone of shelf waters, and by end of summer, in inner zone above bottom depth 50–70 m. By end of metamorphosis, they usually find themselves over suitable for subsidence bottom depths. Subsidence of decapodid stages occurs, as a rule, in benthos with bottom depths no more than 50 m.

In spring larvae were found above bottom depths of more than 300–400 m, in first half of summer, main concentration were in zone of outer and middle shelf, in second half of summer – above inner shelf. In autumn larvae, as a rule, were found above bottom depths less than 50 m. Decapodid stages inhabit in bottom layer above depths less than 40 m.

Distribution of shrimp meroplankton over study area is uneven. One of reasons is impact of surface currents and cyclonic gyres. Hydrological fronts can have significant impact to distribution in plankton and recruitment of benthos shrimp hemipopulation. Activity of larvae can affect their distribution. Larvae can change horizon of their habitat, as well as make horizontal movements within gyres.

– Distribution of shrimp meroplankton over study area is uneven. Mass development

of larvae occurs, as a rule, from May to August, but in some years timing may shift.

– Maximum concentrations of shrimp larvae were about 500 ind./m<sup>2</sup>. Larvae of species of family Crangonidae prevailed. Maximum concentration of shrimp larvae (1410 ind./m<sup>2</sup>) was found in 2015 in early July.

– As development progresses, larvae begin gradually migrate to coast, using compensatory sea currents or moving along large gyres.

### DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

### ACKNOWLEDGMENTS

We thank the crews of research vessels as well as scientific staff of the Pacific Institute of Fisheries and Oceanography for collecting plankton samples and presenting them to us for study.

### REFERENCES

- AquaMaps (AquaMaps Data sources). 2019. URL: <https://www.aquamaps.org/> (Accessed: April 2021).
- Armstrong D.A., Incze L.S., Wencker D.L., Armstrong J.L. 1981. Distribution and abundance of Decapod Crustacean larvae in the southeastern Bering Sea with emphasis on commercial species. *Final Report Outer Continental Shelf Environmental Assessment Program Research Unit*. № 609. P. 479–878.

- Campos J., Van der Veer H.W. 2008. Autecology of *Crangon crangon* (L.) with an emphasis on latitudinal trends. *Oceanography and Marine Biology. An Annual Review*. № 46. P. 65–104. DOI: 10.1201/9781420065756.ch3 (Accessed: April 2021).
- CaRMS (The Canadian Register of Marine Species). 2020. URL: <http://www.marine-species.org/carms/> (Accessed: April 2021).
- Criales M.M., McGowan M.F. 1994. Horizontal and vertical distribution of Peneidean larvae and micronektonic shrimps in the Florida Keys. *Bulletin of Marine Science*. Vol. 54(3). P. 843–856.
- Edwards R., Steele J.H., 1968. The ecology of 0-group plaice and common dabs at Loch Ewe. I. Population and food. *Journal of Experimental Marine Biology and Ecology* 2. P. 215–238. URL: [https://doi.org/10.1016/0022-0981\(68\)90017-8](https://doi.org/10.1016/0022-0981(68)90017-8) (Accessed: April 2021).
- Evans S. 1984. Energy budgets and predation impact of dominant epibenthic carnivores on a shallow soft bottom community at the Swedish west coast. *Estuarine and Coastal Shellfish Science*. Vol. 18(6). P. 651–672. DOI:10.1016/0272-7714(84)90037-4 (Accessed: April 2021).
- Evans S., Tallmark B. 1985. Niche separation within the mobile predator guild on marine shallow soft bottoms. *Marine Ecology – Progress Series*. Vol. 23. P. 279–286. <https://www.jstor.org/stable/24815996?seq=1> (Accessed: April 2021).
- FishBase. 2020. URL: <https://www.fishbase.de/> (Accessed: April 2021).
- Gibson R.N., Yin M.C., Robb L. 1985. The behavioural basis of predator-prey size relationships between shrimp (*Crangon crangon*) and juvenile plaice (*Pleuronectes platessa*). *Journal of Marine Biological Association of the UK*. № 75. P. 337–349.
- Haynes E.B. 1980. Larval morphology of *Pandalus tridens* and a summary of the principal morphological characteristics of North Pacific pandalid shrimp larvae. *Fishery Bulletin* № 77. P. 625–640.
- Haynes E.B. 1981. Early zoeal stages of *Lebbeus polaris*, *Eualus suckleyi*, *E. fabri-cii*, *Spirontocaris arcuata*, *S. ochotensis*, and *Heptacarpus camtschaticus* (Crustacea, Decapoda, Caridea, Hippolytidae) and morphological characterization of zoeae of *Spirontocaris* and related genera. *Fishery Bulletin*. Vol. 79(3). P. 421–440.
- Haynes E.B. 1985. Morphological development, identification, and biology of larvae of Pandalidae, Hippolytidae, and Crangonidae (Crustacea, Decapoda) of the northern north Pacific Ocean. *Fishery Bulletin*. Vol. 83(3). P. 501–521.
- Hostens K. 2000. Spatial patterns and seasonality in the epibenthic communities of the Westerschelde (Southern Bight of the North Sea). *Journal of Marine Biological Association of the UK*. № 80. P. 27–36. DOI: <https://doi.org/10.1017/S0025315499001538> (Accessed: April 2021).
- Hostens K., Hamerlynck O. 1994. The mobile epifauna of the soft bottoms in the subtidal Oosterschelde estuary: structure, function and impact of the storm-surge barrier. *Hydrobiologia*. № 282–283. P. 479–496.
- Ivanov B.G. 1965. Description of the first Far Eastern shrimp larva *Pandalus goniurus*. *Zoologicheskii Zhurnal*. № 44(8). P. 1255–1257 (in Russian).
- Ivanov B.G. 1971. Larvae of some Far Eastern shrimps due to their systematic position. *Zoologicheskii Zhurnal*. Vol. 50(5). P. 657–665 (in Russian with English abstract).
- Kalashnikov B.K., 1984. Study of biology and stocks of shrimp in northern part of the Sea of Okhotsk. Collection of reports

- of the laboratory of marine objects. Okhotskrybvod. P. 13 MS (in Russian).
- Koblikov B.K., Doljenkov V.N., Rodin V.E. et al. 2002. Current state of resources of commercial crustaceans (Decapoda) in Russian Far East basin. Abstracts of VI All-Russian conference on commercial invertebrates. Moscow: VNIRO. P. 20–22 (in Russian with English abstract).
- Konstantinov A.S. 1986. General hydrobiology. Textbook for universities. Moscow: Vysshaya shkola Publ. P. 472 (in Russian).
- Lapinska E., Szaniawska A. 2006. Environmental preferences of *Crangon crangon* (Linnaeus, 1758), *Palaemon adspersus* Rathke, 1837, and *Palaemon elegans* Rathke, 1837 in the littoral zone of the gulf of Gdansk. *Crustaceana* 79. P. 649–662. DOI: 10.1163/156854006778026799
- Luchin V.A., Matveyev V.I. 2016. Interannual variability of thermal state of cold subsurface layer of the Sea of Okhotsk. *Izvestiya TINRO*. № 187. P. 205–216 (in Russian with English abstract). URL: <https://doi.org/10.26428/1606-9919-2016-187-205-216> (Accessed: April 2021).
- Makarov R.R. 1966. Lichinki krevetok, rakovotshelnikov i krabov zapadno-kamchatskogo shelfa i ikh raspredeleniye [Larvae of shrimps, hermit crabs and crabs of the Western Kamtchatka shelf and their distribution]. Moscow: Nauka Publ. P. 164 (in Russian).
- Makarov R.R. 1967. Larvae of the Shrimps and Crabs of the West Kamchatkan Shelf and their Distribution [Translated from Russian by B. Haigh]. The National Lending Library for Science and Technology, Boston Spa, UK. P. 199.
- Marin I.N. 2013. Small Atlas of Decapods of Russia. KMK Scientific Publishing Partnership. P. 145 (in Russian). URL: <https://search.rsl.ru/ru/record/01006594407> (Accessed: April 2021).
- Matilla J., Olafsson E.B., Johannsson A. 1990. Predation effects of *Crangon crangon* benthic infauna on shallow sandy bottoms – an experimental study from southern Sweden. In *24th European Marine Biology Symposium Trophic Relationships in the Marine Environment*. Aberdeen University Press. P. 503–516. <http://www.vliz.be/en/imis?module=ref&refid=6647> (Accessed: April 2021).
- Mikhailova O.G. 2014. Distribution and dynamics of catches of northern shrimp *Pandalus borealis* in the winter-spring period off the southwestern coast of Kamchatka. *Research of aquatic biological resources of Kamchatka and the north-western part of Pacific Ocean*. № 34. P. 22–28 (in Russian with English abstract).
- Modin J., L. Pihl 1996. Small-scale distribution of juvenile plaice and flounder in relation to predatory shrimp in a shallow Swedish bay. *J. Fish Biol.* Vol. 49(6). P. 1070–1085.
- Neves A., Cabral H.N., Gordo L.S. 2007. Distribution and abundance patterns of decapod crustaceans in the Sado estuary, Portugal. *Crustaceana*. Vol. 80(1). P. 97–112. URL: <https://www.jstor.org/stable/20107785?seq=1> (Accessed: April 2021).
- Ouellet P., Allard J.P. 2006. Vertical distribution and behaviour of shrimp *Pandalus borealis* larval stages in thermally stratified water columns: laboratory experiment and field observations. *Fisheries Oceanography*. № 15. P. 373–389. URL: <https://doi.org/10.1111/j.1365-2419.2005.00394.x> (Accessed: April 2021).
- Pedersen S.A., Storm L., Simonsen C.S. 2002. Northern Shrimp (*Pandalus borealis*) Recruitment in West Greenland Waters. Part I. Distribution of *Pandalus* Shrimp Larvae in Relation to Hydrography and Plankton. *J. Northw. Atl. Fish. Sci.* № 30. P. 19–46.

- URL: [https://www.academia.edu/48342307/Northern\\_Shrimp\\_Pandalus\\_borealis\\_Recruitment\\_in\\_West\\_Greenland\\_Waters\\_Part\\_II\\_Lipid\\_Classes\\_and\\_Fatty\\_Acids\\_in\\_Pandalus\\_Shrimp\\_Larvae\\_Implications\\_for\\_Survival\\_Expectations\\_and\\_Trophic\\_Relationships](https://www.academia.edu/48342307/Northern_Shrimp_Pandalus_borealis_Recruitment_in_West_Greenland_Waters_Part_II_Lipid_Classes_and_Fatty_Acids_in_Pandalus_Shrimp_Larvae_Implications_for_Survival_Expectations_and_Trophic_Relationships) (Accessed: April 2021).
- Reise K., 1985. Tidal Flat Ecology. Springer-Verlag, Berlin. P. 191. URL: <https://doi.org/10.1002/iroh.19860710519> (Accessed: April 2021).
- SeaLifeBase. 2021. URL: <https://www.sealifebase.se/search.php> (Accessed: April 2021).
- Sedova N.A. 2019. Morphology and ecology of larvae of brown shrimp in the sea waters of Kamchatka and Chukotka. Petro-pavlovsk-Kamchatsky: Kamchatka State Technical University, P. 180 (in Russian with English abstract).
- Sedova N.A., Grigoriev S.S. 2014. Systematic position of *Neocrangon communis* (Decapoda, Crangonidae) based on the features of larval morphology. *Zootaxa*. Vol. 3827(4). P. 559–575. DOI: 10.11646/zootaxa.3827.4.7 (Accessed: April 2021).
- Sedova N.A., Grigoryev S.S. 2015. Features of larval morphology in *Mesocrangon intermedia* и *Neocrangon communis* (Decapoda: Crangonidae) from the northwestern Pacific. *Zoologicheskii Zhurnal*. № 94. P. 414–428 (in Russian with English abstract).
- Sedova N.A., Grigoriev S.S. 2016. A guide for identification of families and stages of development of larvae of shrimps (Decapoda, Caridea) in near Kamchatka and adjacent waters. *Bulletin of Kamchatka State Technical University*. № 37. P. 77–84 (in Russian with English abstract). DOI: 10.17217/2079-0333-2016-37-77-84. URL: <https://kamchatgtu.ru/wp-content/uploads/2017/04/%D0%92%D0%B5%D1%81%D1%82%D0%BD%D0%B8%D0%BA-37.pdf> (Accessed: April 2021).
- Sedova N.A., Grigoriev S.S. 2017a. A key to identification of shrimp larvae from the family Crangonidae (Decapoda, Caridea) with unabridged development from near Kamchatka waters. *Bulletin of Kamchatka State Technical University*. № 39. P. 65–73 (in Russian with English abstract). DOI: 10.17217/2079-0333-2017-39-65-73. URL: <https://kamchatgtu.ru/wp-content/uploads/2017/04/%D0%92%D0%B5%D1%81%D1%82%D0%BD%D0%B8%D0%BA-39.pdf> (Accessed: April 2021).
- Sedova N.A., Grigoriev S.S. 2017b. A key to identification of shrimp larvae from the family Pandalidae (Decapoda, Caridea) in plankton from marine waters adjacent to Kamchatka. *Bulletin of the North-East Scientific Center, Russia Academy of Sciences Far East Branch* (Magadan). № 4. P. 111–120 (In Russian with English abstract). URL: [http://vestnik.north-east.ru/2017/n4/r\\_Sedova.htm](http://vestnik.north-east.ru/2017/n4/r_Sedova.htm) (Accessed: April 2021).
- Sedova N.A., Grigoryev S.S. 2017c. Morphological features of larvae of *Pandalus eous*, *P. goniurus*, and *P. tridentis* (Decapoda, Pandalidae) from near Kamchatka waters. *Zootaxa*. Vol. 4268(3). P. 301–336. DOI: 10.11646/zootaxa.4268.3.1 (Accessed: April 2021).
- Sedova N.A., Grigoryev S.S. 2018. Morphological features of larvae of the genus *Argis* Kroyer 1842 (Decapoda, Crangonidae) from coastal Kamchatka and adjacent waters. *Zoosystematica Rossica*. Vol. 27(1). P. 11–33. URL: [https://www.zin.ru/journals/zsr/content/2018/zr\\_2018\\_27\\_1\\_Sedova.pdf](https://www.zin.ru/journals/zsr/content/2018/zr_2018_27_1_Sedova.pdf) (Accessed: April 2021).
- Slizkin A.G. 2006. An atlas-guide for crabs and shrimps of the far eastern seas of Russia. Vladivostok: TINRO-center. P. 216 (in Russian with English abstract).

- Slizkin A.G., Bukin S.D., Slizkin A.A. 2001. Horsehair crab (*Erimacrus isenbeckii*) of the North Kuril-Kamchatka shelf: biology, distribution, abundance. *Izvestiya TINRO (Transactions of the Pacific Research Institute of Fisheries and Oceanography)* (Vladivostok). Vol. 128(2). P. 554–570 (in Russian with English abstract).
- Squires H.J. 1993. Decapod Crustacean Larvae from Ungava Bay. *J. Northw. Atl. Fish. Sci.* № 10. P. 168.
- Van der Veer H.W., Bergman M.J.N. 1987. Predation by crustaceans on a newly settled 0-group plaice (*Pleuronectes platessa* L.) population in the western Wadden Sea. *Marine Ecology Progress Series*. № 35. P. 203–215. DOI: 10.3354/meps035203 (Accessed: April 2021).
- Wennhage H., Gibson R.N. 1998. Influence of food supply and a potential predator (*Crangon crangon*) on settling behaviour of plaice (*Pleuronectes platessa*). *Journal of Sea Research*. Vol. 39(1–2). P. 103–112.
- WoRMS (World Register of Marine Species). 2020. URL: <http://www.marinespecies.org/index.php> (Accessed: April 2021).

#### INFORMATION ABOUT THE AUTHORS

**Sedova Nina Anatolievna** – Kamchatka State Technical University; 683003, Russia, Petropavlovsk-Kamchatsky; Doctor of Biological Sciences; Docent; Professor of Water Bioresources, Fishery and Aquaculture Chair; sedova67@bk.ru. SPIN-код: 5638-3959; Author ID: 664456; Scopus ID: 7003300397.

**Grigoriev Sergey Sergeevich** – Kamchatka Branch of Pacific Geographical Institute (KB PGI) FEB RAS; 683000, Russia, Petropavlovsk-Kamchatsky; Candidate of Biological Sciences, Docent, Senior Researcher of Hydrobiology Laboratory; sgr@inbox.ru. SPIN-код: 3010-8053; Author ID: 976830; Scopus ID: 56258333100.