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Notes on the fishes of the Severnaya Zemlya archipelago and the spawning area of polar cod *Boreogadus saida* (Gadidae)

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ABSTRACT

Data on the fishes of the high-latitude Severnaya Zemlya archipelago (the North Land) is presented. The archipelago is located in the Arctic on the border between the Kara Sea and the Laptev Sea. The ichthyofauna of the archipelago has not been studied; therefore, even small collections are of interest. Fish samples were obtained during the expedition "Open Ocean: Arctic Archipelagos – 2019: Severnaya Zemlya". In addition, the samples from this area in the collections of the Zoological Institute (ZIN) were studied, which have been received from polar expeditions to the Kara and Laptev seas during the entire era of polar research. The most significant fact is the discovery of mass accumulation of polar cod *Boreogadus saida* (Lepechin, 1774) larvae in Mikoyan Bay (Bolshevik Island), which gives evidence of important spawning grounds near Severnaya Zemlya. Indirect evidence of this can be found in the publications of polar explorers who overwintered on Severnaya Zemlya in the 1930s–1950s and have reported that the polar cod approaches the shores for spawning in August, in huge schools. The waters of Severnaya Zemlya represent the spawning area of polar cod in the central part of the Eurasian shelf, which is not mentioned in current literature. In addition to polar cod, a few more species are registered in samples from the coastal waters of the archipelago (depths to 38 m), rough hookear sculpin *Artediellus scaber* Knipowitsch, 1907, twohorn sculpin *Icelus bicornis* (Reinhardt, 1840) (family Cottidae), *Liparis tunicatus* Reinhardt, 1836, black-bellied snailfish *L.* cf. *fabricii* (Liparidae), Knipowich eelpout *Gymnelus knipowitschi* Chernova, 1999 (Zoarcidae) and three-spined stickleback *Gasterosteus aculeatus* (Linnaeus, 1758) (Gasterosteidae). In the deepwater straits, snailfish *Careproctus* sp. (174–234 m) and pale eelpout *Lycodes pallidus* Collett, 1879 (105–348 m) were found. The Arctic charr *Salvelinus alpinus* (Linnaeus, 1758) (Salmonidae) inhabits some lakes of the archipelago. This is the first finding of a three-spined stickleback in the east of the Kara Sea.

Key words: *Artediellus*, *Boreogadus*, *Gasterosteus*, *Gymnelus*, *Icelus*, Laptev Sea, *Liparis, Lycodes,* Kara Sea, *Salvelinus,* Severnaya Zemlya, spawning

О рыбах архипелага Северная Земля и районе нереста сайки *Boreogadus saida* (Gadidae)

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РЕЗЮМЕ

Приводятся сведения о рыбах высокоширотного архипелага Северная Земля, расположенного в Арктике на границе морей Карского и Лаптевых. Ихтиофауна архипелага не изучена, поэтому интерес представляют даже небольшие сборы. Материалом послужили экземпляры рыб, собранные в ходе комплексной экспедиции «Открытый Океан: Архипелаги Арктики-2019: Северная Земля», а также рыбы из района архипелага, поступившие в фондовые коллекции Зоологического института РАН (ЗИН РАН) из полярных экспедиций в моря Карское и Лаптевых за весь период исследований. Наиболее значимым фактом является обнаружение в заливе Микояна (о. Большевик) массового скопления личинок сайки ***Boreogadus saida*** (Lepechin, 1774), что свидетельствует о размножении этого вида у Северной Земли. Косвенные свидетельства этому можно найти в трудах полярников, зимовавших на архипелаге в 1930–50-х гг., по сообщениям которых сайка подходит к берегам для нереста в августе огромными стаями. Северная Земля представляет собой не упоминаемый в современной литературе район размножения ***B. saida*** в центральной части евроазиатского шельфа. Помимо сайки, в прибрежных водах архипелага на глубинах до 38 м зарегистрированы шероховатый крючкорогий бычок ***Artediellus scaber*** Knipowitsch, 1907, атлантический двурогий ицел ***Icelus bicornis*** (Reinhardt, 1840) (семейство Cottidae), арктический ***Liparis tunicatus*** Reinhardt, 1836 и чернобрюхий ***L.*** cf. ***fabricii*** липарисы (Liparidae), гимнел Книповича ***Gymnelus knipowitschi*** Chernova, 1999 (Zoarcidae) и трехиглая колюшка ***Gasterosteus aculeatus*** (Linnaeus, 1758) (Gasterosteidae). В глубоководных проливах найдены карепрокты ***Careproctus*** sp. (174–234 м) и бледный ликод ***Lycodes pallidus*** Collett, 1879 (105–348 м). Арктический голец ***Salvelinus alpinus*** (Linnaeus, 1758) (Salmonidae) обитает в некоторых озерах архипелага. Это – первая находка трехиглой колюшки на востоке Карского моря.

Ключевые слова: *Artediellus*, *Boreogadus*, *Gasterosteus*, *Gymnelus*, *Icelus*, море Лаптевых, *Liparis, Lycodes*, Карское море, *Salvelinus alpinus*, Северная Земля, нерест

INTRODUCTION

Severnaya Zemlya is a vast archipelago (37 thousand km²), lying in the Arctic Ocean on the border between the Kara Sea and the Laptev Sea (77°55´11.21″ – 81°16´22.92″N, 90°4´42.95″ – 107°45´ 55.67″E). It includes many small islands and 4 major ones (Bolshevik I., October Revolution I., Komsomolets I. and Pioneer I.) (Fig. 1). The region of the archipelago, with a harsh arctic climate, is difficult to access, as the surrounding waters are ice-packed almost all year round. The archipelago was discovered in 1913 by the Hydrographic Expedition of the Arctic Ocean (GESLO) on the icebreaking steamers (i/b) "Vaigach" and "Taymyr" under the leadership of B.A. Vilkitsky (Laktionov 1936; Savatyugin and Shevnina 2003; Savatyugin and Dorozhkina 2010). The first survey of the archipelago including its mapping and a general environmental description was carried out in 1930–1932 by the expedition of the All-Union Arctic Institute (Urvantsev 1935; Ushakov 1951; Shneider 2021).

The archipelago is unique from a zoogeographic point of view. It is equally distant from both the Pacific and the Atlantic gateways to the Arctic Ocean, from where the boreal marine species can penetrate into the Arctic. Such location determines the specifics of the composition of the marine fauna. This is the area of contacts between the species and populations of the Atlantic and Pacific faunistic complexes, the zone of contact of the West-Arctic and East-Arctic ranges (Semenov 1989; Sirenko et al. 2009). The shelf-slope and depths of the Central Arctic Ocean (or Polar Basin) approach Severnaya Zemlya on the northeast and east, from where bathyal fauna can enter the straits of the archipelago. The important zoogeographic boundary of the Palaearctic, the Yenisey faunistic division, approaches from the south (Rogacheva 1987). The latitudinal boundary runs along the Krasnoy Armii Strait in the middle part of the archipelago, separating 2 sub-provinces of the Desert-Arctic Province (Belikov and Randla 1987).

Marine biota of the archipelago is poorly studied. Especially, this can be applied to the coastal zone.

Almost nothing was known about the biodiversity, distribution and ecology of various groups of animals inhabiting bays and inlets, the straits between the islands of the archipelago and its glacial fjords. Limited studies of the zooplankton and benthic communities of Severnaya Zemlya have been carried out in the Shokalsky and Vilkitsky straits (Khmyznikova 1937; Virketis 1943; Gorbunov 1946). A brief description of the coastal biocenoses was carried out based on a scuba-dive survey at the Sredniy Island (the west of the archipelago) (Averintsev 1989). The ichthyofauna of the archipelago has never been purposefully studied. Scattered brief information on fish can be found in a few works. In his essays on the fishes of the islands of the Soviet Arctic, N.N. Burmakin (1957) mentioned 4 fish species for Severnaya Zemlya, "polar cod, eelpout, snailfish and four-horned sculpin". He obtained that information from the biologist N.P. Demme, who led the overwintering station on the Domashniy Island in 1932–1934, the west of the archipelago (Avetisov 2014). A few specimens of 2 species, twohorn sculpin *Icelus bicornis* (Reinhardt, 1840) and rough hookear sculpin *Artediellus scaber* Knipowitsch, 1907, were caught near Domashniy and Pioneer islands during the expedition on board icebreaking steamer "G. Sedov» (Esipov 1933; Yessipov 1933). Fragmentary notes on the fishes of the archipelago can be found in the reports on the ichthyofauna of the Kara Sea (Esipov 1952) and on the Liparidae of the Eurasian Arctic (Chernova 1991; Chernova in Dolgov et al. 2018). The data given in other publications (Borkin et al. 2008; Dolgov et al. 2008, 2018; Orlov et al. 2020a, b) do not include fish records from the area of Severnaya Zemlya. Thus, even small new samples from the waters of the archipelago are of interest.

The multidisciplinary expedition "Open Ocean: Arctic Archipelagos-2019: Severnaya Zemlya" (hereinafter – the expedition O2A2-2019), carried out zoological, hydrobiological, geomorphological and other studies on the islands (Gavrilo et al. 2019, 2020). A few collected fishes were transferred to the Zoological Institute of Russian Academy of Sciences (ZIN) by the expedition leader M.V. Gavrilo. Their processing served as a reason to summarize the available materials on the fishes of Severnaya Zemlya. For this, an analysis was performed on the ZIN collections, which included specimens obtained from polar expeditions to the Kara and the Laptev seas over the entire historical period of the study. Among them, there are several fishes from the waters of Severnaya Zemlya: from the GESLO expedition, collected by the ship's doctor L.M. Starokadomsky (i/b "Taymyr"); samples collected by L.O. Retovsky (1932) and G.P. Gorbunov (1933 and 1935) on board of i/b "A. Sibiryakov"; by G.P. Gorbunov (1937) on board of i/b "Sadko"; and by V.D. Vagin during the voyages of icebreakers "G. Sedov" (1934) and "F. Litke" (1948). This article summarizes all information on the ichthyofauna of the archipelago: literature data, collections of the expedition A2O2-2019 and materials stored in ZIN.

MATERIALS AND METHODS

Research area. The high-Arctic position of Severnaya Zemlya determines its significant glaciation: about 47% of the area of these islands (17.5 thousand km²) is covered with glaciers; glacial shores occupy up to 14% of the coastline, and the iceberg calving is active. Permafrost lays below the depth of 0.3–0.9 m (Bolshiyanov and Makeev 1995). The fast-ice thickness ranges from 1.3 to 1.7 m; in harsh years fast-ice can survive summer thus forming two-year fast-ice of over 2 m (Borodkin et al. 2018). Averintsev (1989) reported 2.5 to 5 m thick coastal ice.

The climate in the region of the archipelago is arctic marine, with a mean annual air temperature of −14.8°C. Monthly average temperature ranges from −28°C in February to +2.7°C in July or August. In summer, air temperatures can rise up to +15°C; the minimum-recorded temperature in winter was −50.7°C. The duration of the polar night is at least 122 days. Freezing of the sea takes place in September–October and sea ice melts in July–August (Govorukha and Bogdashevsky 1970; Bryazgin and Yunak 1988; Bassford et al. 2006). The large islands have a hydrographic network with 9 rivers of 20 to 64 km long. The area of most of the lakes does not exceed 3 km², and the largest lake (about 60 km²) is located on the Bolshevik Island (Bolshiyanov and Makeev 1995).

The expedition O2A2-2019. The expedition O2A2-2019 aboard R/V "Professor Molchanov" (16.08–18.09.2019) carried out for the first time a comprehensive survey of the Severnaya Zemlya Archipelago coastal zone. The hydrobiological project of the scientific program included water column profiling, sediment sampling for granulometry and organic carbon, and sampling for plankton, zoobenthos,

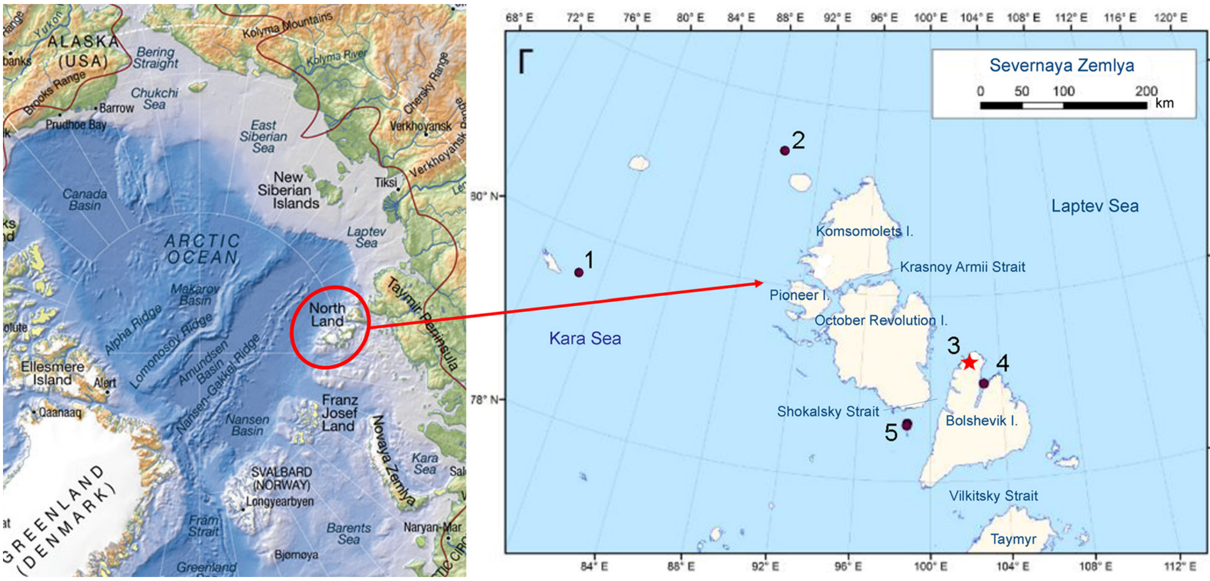

Fig. 1. Localities of the fishes (solid circles, one is covered with a star) sampled by Expedition O2A2-2019. The star (3, Mikoyan Bay) marks the spawning area for polar cod. *Gymnelus knipowitschi* (1 – ZIN 56680, 3 – ZIN 56681), *Boreogadus saida* (2 – ZIN 56683, 3 – ZIN 56684 and larvae), *Liparis* cf. *fabricii* (4) and *Artediellus scaber* (5). Map on the left: Nordpil.com – custom maps and visual communication (https://nordpil.com/static/images/arctic_topographic_map_full.jpg).

macroalgae and microphytobenthos. Scuba-divers conducted video recording and benthos sampling. In total, 55 stations were performed (34 shipboard, 13 coastal, 7 scuba-dives, 1 from a boat) (Gavrilo et al. 2019, 2020). There were no targeted fish studies and fishes were collected opportunistically when possible or caught with benthos samplings. The fish collection includes 7 samples. The coordinates of their localities (Fig. 1) were fixed by GPS. According to the expedition data, the coastal habitats where fishes were collected by scuba-divers, had the following characteristics. 1) Bolshoy I. (Krasniflotskie Islands), coastal waters to the depths of 25 m were homogeneous with temperatures just above zero, and salinity just below 30. Strong currents along the coast were observed there and bottom sediments consisted of sand and gravel. Many pieces of icebergs were present. 2) Coastal habitats in Mikoyan and Akhmatov bays with the depths down to 50 m are affected by glacial meltwater and river discharge. Surface waters (down to 3–5 m) are warmed up to 5–7°C and freshened. Below, down to 20 m, the homogeneous layer with temperatures slightly above zero, and salinity often below 30, was observed. Deeper, the waters become colder and more saline.

Gears. Part of the collection was made when fishes got into the benthic gears, bottom grab and epibenthic trawl. Several specimens were caught while diving. Fish larvae were caught in a ring-net for catching plankton (mesh size of 200 μm) near the shore during disembarkation.

The grab "Ocean" (0.1 m^2) was used to take samples of macrobenthos at ship stations. Samples collected from the sieve were fixed after washing.

The epibenthic trawl (horizontal opening 1 m, mesh size 1000 μm) was an enlarged model of the K.W. Ockelman sledge modified by A. Basin and V. Spiridonov. The fish were caught by trawling carried out on the northwest shelf of the archipelago. Trawling was performed in the drift of the vessel by etching more than 2 depths of the cable.

Diving stations were carried out by 2 pairs of divers; in each pair one was collecting material, the other was filming. In Mikoyan Bay, the diving was done near a grounded iceberg. The diving in Akhmatov Bay began from the coast of a small (no more than 20 m in diameter) islet, not indicated on the map. The routes passed within a radius of 50–70 m from the dive point. The expedition cameraman A.P. Kamenev, using the technique of artistic macro photography, photographed live fishes.

The fishes were fixed with a formalin solution in filtered seawater to a final concentration of 4%. Photos of fixed specimens were made in the ZIN.

The osteological characters of the fishes were studied using radiographs. The number of vertebrae includes the urostyle. Photos, except for Fig. 6A, were taken by N.V. Chernova.

Abbreviations: *TL* – total length, *SL* – standard length, *D* – dorsal, *A* – anal, *P* – pectoral and *C* – caudal fins.

In the list, the bracketed species were recorded adjacent to Severnaya Zemlya and one can expect them also to occur in the waters of the archipelago.

List of fishes collected by the expedition O2A2-2019 (complete location data are given in the Table 1). *Boreogadus saida* (Lepechin, 1774). Larvae (n=16), *TL* 15.0–23.5 mm, caught in the top of Mikoyan Bay (I. Bolshevik, 79°13.80´N 102°15.60´E) near the coast by a ring-net, 01.09.2019; collectors M.V. Gavrilo and K.A. Kosobokova. Adults: ZIN No. 56684, *TL* 141 mm, *SL* 127 mm; ZIN No. 56683, *TL* 67 mm, *SL* 59 mm. – *Artediellus scaber.* ZIN No. 56682, *TL* 73 mm, *SL* 60 mm; field identification: "sculpin". – *Liparis* cf. *fabricii* Krøyer, 1847. ZIN No. 56679, *TL* 100, *SL* 86 mm. – *Gymnelus knipowitschi* Chernova, 1999. ZIN No. 56680, female *TL* 101 mm, *SL* 98 mm; field identification: "presumably blenny" [=*Lumpenus* Reinhardt, 1836]; ZIN No. 56681, male *TL* 134 mm, *SL* 130 mm; field identification: "eelpout".

Data on the locations of fishes from the ZIN collection is given in Table 1 (see also catalogs published by ZIN: Sideleva et al. 2006a, 2006b; Dorofeyeva and Prirodina 2011; Balushkin et al. 2012).

RESULTS AND DISCUSSION

1. Severnaya Zemlya – spawning area of the polar cod

In late August – early September, in Mikoyan Bay (the north of the Bolshevik I., 79°13.80´N 102°15.60´E), mass accumulation of polar cod larvae was observed. According to the expedition participants, when crossing the bay in a rubber boat, the water was teeming with larvae. The larvae were so abundant that it was possible to scoop them from the boat by an ordinary ring-net. Polar cod larvae caught in this way had a length *TL* of 15.0–23.5 (on average 19.5) mm. The larvae were likely not advected from the open sea, because the mouth of the bay and the outlet from it were closed by residual (winter) ice. And larvae cannot be drifted by deeper water currents into the bay, as both eggs and small larvae are concentrated close to the underside of the ice (Rass 1949; Ponomarenko 2000). The above fact clearly indicates that spawning of *B. saida* occurs in the area of Severnaya Zemlya (Fig. 1).

Fig. 2. Larvae of polar cod *Boreogadus saida*, *TL* 15.0–23.5 mm, Severnaya Zemlya, Mikoyan Bay.

Description. *TL* 15.0–23.5 mm. The mouth is superior (Fig. 2); in the body cavity, there are remnants of the yolk. Pigmentation includes a group of large melanophores at the occiput and a row of pigment cells on the dorsum along the base of the fin fold. The abdominal cavity is pigmented dorsally; a number of small melanophores are present along the midline of the posterior half of the tail.

Known spawning grounds. The polar cod has a huge circumpolar range, but currently only 2 spawning grounds are usually indicated for Eurasia. Both are located in the Barents Sea region: one is offshore the southeastern Spitsbergen, the other is to the southeast, i.e. the Pechora Sea (Ponomarenko 1968; Pechenik et al. 1973; Ajiad et al. 2011; Oganin and Borkin 2013; Eriksen et al. 2020; Aune et al. 2021). In some years, the latter spawning area expands eastwards into the adjacent waters of the Kara Sea: into Kara Bay (Probatov 1934; Moskalenko 1964) and into the bays in the southeast of Novaya Zemlya (Ponomarenko 1968; Borkin 1990; Oganin and Borkin 2013). Spawning in the Pechora region occurs during warm years. During cold climatic periods, the spawning area of this polar cod population shifts westward, towards the shores of the Kanin Peninsula and into the White Sea (Ponomarenko 1968; Pechenik et al. 1973; Oganin and Borkin 2013).

For the eastern sector of the Russian Arctic, polar cod spawning is noted in Anabar Bay of the Laptev Sea (Moskalenko 1964). Reproduction is indicated in January, in ice-covered coastal areas. Polar cod does not penetrate under the ice far from its edge, and with a strong development of fast ice it moves seawards from the coast. In the Canadian Arctic, spawning is known in the Beaufort Sea (Steffansson Sound), where it occurs in winter under the ice (Craig et al. 1982; Graham and Hop 1995).

Thus, the area of Severnaya Zemlya represents another spawning ground of polar cod, located in the central part of the Eurasian shelf, approximately equidistant from the Atlantic and Pacific Oceans. This breeding area is not mentioned in contemporary sources. However, reports on the inshore spawning migrations of polar cod to Severnaya Zemlya can be found in the publications of polar explorers of the 1930s–1950s. For example, N.N. Urvantsev (1935: 359), who overwintered on Severnaya Zemlya in 1930–1932, reports that "polar cod approaches the shores in August for spawning, in huge schools of hundreds of thousands and millions of individuals". This observation is confirmed by later evidence. "In the fall of 1940, during the spawning of polar cod and during the passage of a herd of beluga whales, huge masses of polar cod were thrown ashore by waves. The staff of the polar station [on the Domashniy Island – N.Ch.] collected about 2 tons of it, and no less than this amount remained on the shore" (Laktionov 1946).

Some ideas about the scale of migrations of polar cod inshore are given by the following evidence of N.P. Demme. In 1932, polar cod was thrown ashore by storm in huge numbers, forming a continuous massive band about 5 m wide by a rough estimate, presenting up to 40 fish per square meter, or about 3–5 kg per 1 m of coastline (Burmakin 1957). These polar explorers used polar cod for food, so they could conclude that these schools consisted of spawning individuals.

These observations indicate, firstly, the presence of spawning grounds for polar cod near Severnaya Zemlya; secondly, that the reproduction is regular in these waters; and, thirdly, that the scale of spawning is significant. Considering the massiveness of approaches, it can be assumed that spawning of polar cod occurs not only in the Mikoyan Bay, but also near other islands of the archipelago.

What "form" of polar cod breeds near Severnaya Zemlya?

Polar cod is known to be heterogeneous (phenotypically, genetically and ecologically variable) throughout its vast range (Chernova 2018; Gordeeva and Mishin 2019; Nelson et al. 2020). Data about the "forms" or "stocks" of polar cod are fragmentary, sometimes contradictory. For the southeast of the Barents Sea, the existence of 2 distinct "forms" (phenotypes, ecologically distinct) is assumed: coastal and typical oceanic; 2 types of corresponding larvae are distinguished by color and morphometry (Kashkina 1962). "The oceanic polar cod makes long migrations, is connected in its distribution with ice and reaches the highest latitudes; ... when approaching the shores for spawning, it mixes with the local (coastal and fiord) forms" (Kashkina 1962: 112). Moskalenko (1964) reports about 2 "forms" of polar cod inhabiting the Barents and Siberian seas. In his opinion, the small-sized Siberian form differs from the large-sized Barents Sea form in growth rate, in the shape of the caudal fin, and in color (light grayish-yellow, with the absence of the lilac skin tone that is characteristic for a typical polar cod from the latter area). The Siberian form lives in the coastal regions of the Kara and Laptev seas and occurs in the warmer and freshened waters of bays and inlets during summer. The oceanic form is usually found in open seawaters at negative temperatures and high salinity; it appears in the coastal zone only in the prespawning and spawning periods. The two forms can occur together sometimes.

In the entire Russian sector of the Arctic, the presence of a few populations or "stocks" of polar cod is indicated. They differ in spawning areas, feeding places and migration routes. Two are located in the Barents and Kara Seas: Spitsbergen (north-western) and Novaya Zemlya (south-eastern) populations (Oganin 2013; Aune et al. 2020). At least one is in the Chukchi and Bering Seas; another one, presumably, inhabits the Laptev and East Siberian seas (Ponomarenko 1968). Photographs give an idea of the differences between polar cod from separate geographical areas (Chernova 2018).

One bird-caught specimen found on the shore of Mikoyan Bay obviously belongs to the population of polar cod that spawns there. It was a female

Fig. 3. Polar cod *Boreogadus saida*, “black” form, Mikoyan Bay of the Bolshevik Island (ZIN No. 56684, *TL* 141 mm, SL 127 mm).

SL 127 mm (Fig. 3) with gonads at maturity stage IV (ZIN No. 56684). Since the specimen was dropped by a seabird, it appears to have been caught in surface waters around the archipelago.

Description. Head length (*c*) is 27.6% *SL*, eye diameter 25.7% *c*. The snout is oblique, pointed. Chin barbel is 1/5 of the eye diameter. Vertebrae 55 (19 + 36). Fins: D_1 12, D_2 14, D_3 18; A_1 16, A_2 18. *C* 22/4/22. The caudal-fin lobes are pointed. The body is intensely pigmented, almost completely black; the dorsal fins are dark gray with a black margin; the anal fins are gray.

It can be concluded that this “black” polar cod breeds near Severnaya Zemlya. It is more consistent with the “oceanic form”. However, it is not completely identical with specimens from the western part of the Kara Sea or the Laptev Sea (Chernova 2018) in terms of the features of the shape of the head and body, details of the coloration of the fins. Possibly, polar cod from the central part of the Arctic Ocean approaches the archipelago to spawn. Its mass accumulations are known under multi-year ice up to the highest latitudes (Andriashev et al. 1980; Melnikov and Chernova 2013).

It should be noted that the second specimen of polar cod from expedition O2A2-2019 does not belong to this “black” form. It was found northwest of the archipelago, at a distant location from Mikoyan Bay. This northern specimen of polar cod (juvenile *SL* 59 mm) was caught near the bottom at a depth of 105 m (Fig. 4). Head length (*c*) 28.8% *SL*, eye diameter 30.0% *c*. Vertebrae 54 (17 + 37). It differs from the “black” form in its lighter color. Unusual is the presence of transverse dark bands on the sides above the pectoral fin. Such atypical coloration of polar cod was noted earlier: specimens of the “banded” form (Fig. 5) were numerous in trawl catches in the southwestern part of the Kara Sea (N. Chernova, cruise of the R/V “Dalnie Zelentsy”, August-September 2012).

Spawning time. Polar cod is known to spawn under the ice starting from the freezing period. In the Barents Sea the spawning was recorded in mid-December to March, most intensively in January–February (Ponomarenko 2000; Oganin and Borkin 2013). In Kara Bay, polar cod spawning was noted in mid-January (Ivanova 1959; Moskalenko 1964). But off the east coast of Novaya Zemlya the spawning may take place as early as October–December (Ponomarenko 1968; Borkin 1990). This shift in time may be caused by the earlier dates of ice formation in the more eastern and northern areas. Since the freeze-up period near Severnaya Zemlya begins in September–October, it can be assumed that spawning of polar cod in these waters may start at the same time. This corresponds to the observations of N.N. Urvantsev (1935) on the spawning approaches of polar cod to Severnaya Zemlya in August. There is also the report of A.F. Laktionov (1936: 141): sometimes polar cod approach the shores in autumn in huge schools, and then serve as food for ringed seals, bearded seals and beluga whales.

The timing of polar cod embryonic development. Under experimental conditions, at a temperature of 0°C, the absorption of the yolk sac was completely finished 22–24 days after hatching (White Sea population) (Aronovich et al. 1975); at 3.5°C the yolk sac depleted in *c.* 7–13 days (Cambridge Bay, Nunavut, Canada) (Kent et al. 2016). The metamorphosis from larvae to pelagic juveniles was completed in the size range *TL* 27–35 mm (Ponomarenko 2000). The given data, as well as the length of the caught larvae (*TL* 15.0–23.5 mm in the first days of September) and the incomplete resorption of the yolk, allow assuming

Fig. 4. Polar cod *Boreogadus saida*, “banded” form (designated by lines) caught to the northeast of Severnaya Zemlya (ZIN No. 56683, *SL* 59 mm).

Fig. 5. Polar cod *Boreogadus saida*, “banded” form caught in the southwestern part of the Kara Sea (73°44.5 N, 70°31.8 E), depth 20.5 m; fresh specimen *TL* 115 mm.

that, under conditions of lower temperatures, their hatching could occur around the beginning of August. This corresponds to the period of sea ice melting in the waters of the archipelago (July–August). Other authors also suggest that the hatching coincides in time with the break-up and melting of the sea ice (Yudanov 1976; Ponomarenko 2000).

Egg development is temperature-dependent. At 3.5°C, hatching started 29 days after fertilization (Cambridge Bay) (Kent et al. 2016). At a temperature of 0°C, the duration of embryonic development is 26–35 days (Aronovich et al. 1975), at a temperature of –1.5°C it is up to 80 days (White Sea) (Altukhov 1981). According to generalized data from lower latitudes, the incubation period lasts from 1–3 up to 5 months (Rass 1968; Borkin 1990; Kent et al. 2016). Taking into account the periods of ice formation (September–October) and melting (July–August), it can be assumed that embryonic development of polar cod may last for up to 9 months in the region of Severnaya Zemlya (from October–November to July).

2. Fishes caught in the waters of Severnaya Zemlya archipelago

The materials from expedition O2A2-2019 include fish of 4 species from the coastal shallow waters. In addition to polar cod, these are the rough hookear sculpin *Artediellus scaber*, black-bellied snailfish *Liparis* cf. *fabricii* and Knipovich eelpout *Gymnelus knipowitschi*. According to the materials stored in the ZIN collections and reliable literature data, the twohorn sculpin *Icelus bicornis* and the Arctic snailfish *Liparis tunicatus* Reinhardt, 1836 are added for shallow waters. *Careproctus* sp. and pale eelpout *Lycodes pallidus* Collett, 1879 are recorded in straits at a depth of 105 to 348 m. The Arctic charr *Salvelinus alpinus* (Linnaeus, 1758) (Salmonidae) is present in a freshwater lake. Taking into account three-spined stickleback *Gasterosteus aculeatus* (Linnaeus, 1758) (Gasterosteidae) caught nearby, 10 species in 9 genera and 6 families have been recorded in the waters of Severnaya Zemlya. In addition, 3 more species are known in close vicinity: the Arctic staghorn sculpin

Gymnocanthus tricuspis (Reinhardt, 1830) in the shallows and 2 species of *Lycodes* Reinhardt, 1831 at a greater depth. We give the complete information on these fishes below.

Marine fishes

Family Gadidae

2.1. *Boreogadus saida* – polar (or Arctic) cod.

In publications, polar cod was recorded in benthic samples, made at the Domashniy I., depth 24 m, and in the northern part of the Shokalsky Strait at a depth of 145 m, at a temperature from −1.69 to −0.9°C, salinity 34.47 psu (Esipov 1933; Gorbunov 1946; Esipov 1952).

During the scuba-dives carried out by expedition O2A2-2019, the divers noted each time the wide distribution of juvenile polar cod in the coastal waters of the archipelago, including the areas with sugar kelp *Saccharina* Stackhouse, 1809 [=*Laminaria*]. Our observations from the vessel (M. Gavrilo) recorded mass feeding of the kittiwakes *Rissa tridactyla* (Linnaeus, 1758), glaucous gull *Larus hyperboreus* Gunnerus, 1767, Heuglin's gull *L. hueglini* Bree, 1876, Pomarine skua *Stercorarius pomarinus* (Temminck, 1815) and beluga whales *Delphinapterus leucas* (Pallas, 1776) on polar cod schools in surface waters (Gavrilo et al. 2019). This confirms once again that polar cod is abundant in the archipelago area, and is a key-species in the cryopelagic food-web.

In the ZIN collections the specimens of polar cod from Severnaya Zemlya have been collected mainly at a depth of 112–371 m by a Sigsbee trawl (Table 1). Most of these samples were made by V.L. Vagin in 1948 onboard the i/b "F. Litke" northeast of Komsomolets I., southwest off October Revolution I., in the eastern part of the Shokalsky Strait, east and south off Bolshevik I. and in the Vilkitsky Strait.

Family Cottidae

2.2. *Artediellus scaber*– rough hookear sculpin (Fig. 6).

The species was reported from the west of Severnaya Zemlya (Pioneer I. and Domashniy I.) in samples made from i/b "G. Sedov" (1930) at a depth of 24 m, at a bottom temperature of −0.9°C (Yessipov 1933; Esipov 1933, 1952). The ZIN collections contain specimens obtained from Vilkitsky Strait (closer to the coast of Taymyr Peninsula, at depths of 28–32 m) sampled by the Russian Polar Expedition (1901) and GESLO (1913) (Table 1).

A specimen of *TL* 73 mm (ZIN No. 56682) was caught by expedition O2A2-2019 near the Bolshoy I. (in the group of the Krasnoflotsk islands, Severnaya Zemlya). It was collected by a diver at a depth of 7–15 m, on a rocky bottom among thickets of red algae. The morphology of the sculpin corresponds to the description of Andriashev (1954). Vertebrae 31 (10+21). Fin rays: D_1 9, D_2 13; *A* 13, *V* 3, *P* 16, *C* 23 (8+11 + 4). Lateral line 28. Life color is variegated.

In the Kara Sea, this arctic species was recorded along the Taymyr coast at depths of 9–38 m, in the waters with a negative temperature and salinity of 29.6–32.5 psu (Esipov 1952). *Artediellus scaber*, apparently, is a common inhabitant of the coastal zone of the Arctic archipelagos. In the area of Franz Josef Land, it was found in a similar habitat, in the kelp zone among red algae and sugar kelp at depths from 6 to 21 m (Chernova et al. 2014). Other captures of this species and sculpins mentioned below (Borkin et al. 2008; Dolgov et al. 2008, 2018) were made not in the area of Severnaya Zemlya.

2.3. *Icelus bicornis* – twohorn sculpin

In the coastal zone of Domashniy I., *I. bicornis* was caught in shallow waters of 24 m, and in the Shokalsky and Vilkitsky straits, the species was recorded at a depth of 100–145 m (Esipov 1933; Gorbunov 1946; Esipov 1952). It was found in waters with negative temperature ranged from −1.69 to −0.9°C (Gorbunov 1946; Esipov 1952). The ZIN collections contain specimens from the Shokalsky Strait (ZIN No. 32778). There are also a few specimens obtained by the Russian Polar Expedition (1901–1902) in the Kara Sea off the coast of Taymyr Peninsula at depths of 13–38 m (ZIN No. 14237–14241, not included in Table 1).

In the Kara Sea, twohorn sculpin is one of the most common fishes, which inhabits the depths from 17 to 560 m at temperatures from −1.82 to −0.57°C and salinity of 33–35 psu (Esipov 1952). Immature fish are found more often over a depth range from 40 to 60 m; adult fish prefer the range of 80–180 m.

[*Gymnocanthus tricuspis* – Arctic staghorn sculpin]

The species is likely to be found in the coastal area of Severnaya Zemlya. This Arctic species inhabits shallow waters of the Taymyr Peninsula at depths of up to 30 m (Esipov 1952). The ZIN funds contain specimens from the Cape Chelyuskin, southern side of the Vilkitsky Strait (Table 1).

Fig. 6. Rough hookear sculpin *Artediellus scaber*, Bolshoy Island: A – *in vivo* (photo by A.P. Kamenev); B – the same specimen (ZIN No. 56682, *TL* 73 mm).

Questionable sculpin records. In the waters of the archipelago, the fourhorn sculpin *Myoxocephalus quadricornis* (Linnaeus, 1758) was noted; several specimens were caught in September 1932 by a dredge near the coast of Domashniy I. (Burmakin 1957). However, the ZIN collections do not contain a single specimen of this species from the area of Severnaya Zemlya, as well as from offshore. All ZIN specimens from the Kara and Laptev seas had been caught in brackish waters of estuarine areas. Esipov (1952) also stated that the species dwells exclusively in low salinity waters. More likely, Burmakin's indication refers to sculpins of the genera *Artediellus* Jordan, 1885, *Icelus* Krøyer, 1845 or *Gymnocanthus* Swainson, 1839 rather than to *M. quadricornis.* This equally applies to the "sculpins" from the coast of the Sredniy I. (west of Severnaya Zemlya), recorded at depths up to 15–20 m in the biocenosis of sugar

Table 1. Locations of the fishes from the area of Severnaya Zemlya, literature records and ZIN collections (listed in the order in which they appear in the text)

References or ZIN Nos	Locations	Collectors
	Marine fishes	
	Family Gadidae	
	1. *Boreogadus saida*	
Esipov 1933	Domashniy I., 79°30´N 91°18´E, i/b "G. Sedov", 25.08.1930, depth 24 m, st. 52, Sigsbee trawl, ground–gravel, sand; t –0.9°C [10–12 specimens *TL* 52–83 mm].	G.P. Gorbunov and V.K. Esipov
Gorbunov 1946; Esipov 1952	North of the Shokalsky Strait, 79°15.4´N 100°04´E, depth 145 m, 20.08.1932, i/b "V. Rusanov", st. 18, ground – stones, gray silt, sponges; t –1.69°C, S 34.47 psu, 2 spec.	V.L. Vagin and N.N. Kondakov
27141	North-east of Komsomolets I., 81°24´N 96°54´E, 16.08.1932, i/b "A. Sibiryakov", 5 spec.	L.O. Retovsky
31985	South of Bolshevik I., 78°06´N 102°57´E, depth 150 m, 09.09.1948, i/b "F. Litke", st. 176, 1 juv.	V.L. Vagin
31988	South-west of October Revolution I., 78°32´N 97°55´E, depth 112 m, 1948, i/b "F. Litke", st. 113, 1 spec.	V.L. Vagin
31989	Vilkitsky Strait, 78°53´N 100°15´E, depth 250 m, i/b "F. Litke", 12.07.1948, st. 120, 1 juv.	V.L. Vagin
32000	East of Bolshevik I., 79°02´N 107°01´E, depth 371 m, 31.08.1948, i/b "F. Litke", st. 138, 1 spec. + juv.	V.L. Vagin
32002	East part of the Shokalsky Strait, 79°30´N 101°47´E, depth 234 m, 27.08.1948, i/b "F. Litke", st. 126, 2 spec.	V.L. Vagin
32003	East of Bolshevik I., 79°28´N 105°12´E, depth 125 m, 30.08.1948, i/b "F. Litke", st. 136, 2 spec.	V.L. Vagin
49981	October Revolution I., 24.09.1985, 14 spec.	M.V. Gavrilo
56683	North of Schmidt I., 81°33.20´N 089°14.32´E, depth 105 m, 24.08.2019, R/V "Prof. Molchanov", st. 4a, epibenthic trawl; ground–gravel, aleurite, 1 spec.	A.B. Basin, V.L. Syomin, V.A. Spiridonov and A.S. Solomatov
56684	Bolshevik I., shore of Mikoyan Bay, 79°13.80´N 102°15.60´E, 01.09.2019, R/V "Prof. Molchanov"; 1 spec., dropped by a seabird	A.V. Ezhov and V.M. Mel'nik
	Family Cottidae	
	2. *Artediellus scaber*	
Yessipov 1933	Severnaya Zemlya, west of Pioneer I., 79°59´N 91°13´E, [25–30.08.]1930, i/b "G. Sedov", Sigsbee trawl	G.P. Gorbunov and V.K. Esipov
Esipov 1933, 1952	Domashniy I., 79°30´N 91°18´E, i/b "G. Sedov", 25.08.1930, depth 24 m, st. 52, Sigsbee trawl, ground–gravel, sand; t –0.9°C, 3 juv.	G.P. Gorbunov and V.K. Esipov
Esipov 1952	Vilkitsky Strait, at Cape Chelyuskin (Taymyr), 77°41´N 104°15´E, depth 11–13 m, 8.09.1933, i/b "A. Sibiryakov", st. 28, ground–pebbles, algae; 1 spec.	G.P. Gorbunov and V.L.Vagin
14203-04	South-west of the Vilkitsky Strait, off Taymyr coast, 76°59´N 100°19´E, depth 28 m, 31.08.1901, steam- and sail-powered brig "Zarya", st. 44, 16 spec.	Russian Polar Expedition
32803	South of Maliy Taymyr I., 77°54´N 107°00´E, depth 32 m, 02.09.1913, i/b "Taymyr", 6 spec.	L.M. Starokadomskiy
56682	Krasnoflotskie islands, Bol'shoy I. (opposite the Polar station), 78°37.96´N 98°43.46´E, depth 7–15 m, 30.08.2019, R/V "Prof. Molchanov", st. 26, diver's sample, 1 spec.	V.L. Syomin, S.A. Kovalyov, A.I. Tereschuk, V.V. Sokolov and V.A. Spiridonov
	3. *Icelus bicornis*	
Esipov 1933, 1952	Domashniy I., 79°30´N 91°18´E, depth 24 m, 25.08.1930, i/b "G. Sedov", st. 52 and 53, ground–pebbles, sand; t –0.9°C, 2 juv. + 1 spec.	G.P. Gorbunov and V.K. Esipov

References or ZIN Nos	Locations	Collectors
Gorbunov 1946; Esipov 1952	Northern part of the Shokalsky Strait, 79°15.4´N 100°04´E, depth 145 m, 20.08.1932, i/b "V. Rusanov", st. 18, ground–stones, gray silt, sponges; t –1.69°C, S 34.47 psu, 3 spec.	V.L. Vagin and N.N. Kondakov
Esipov 1952	Vilkitsky Strait, 77°46.5´N 100°19´E, 8.09.1932 i/b "V. Rusanov", st. 32, depth 100 m, ground–sand; t –1.61°C, S 34.3 psu, 1 spec.	V.L. Vagin and N.N. Kondakov
32778	Northern part of the Shokalsky Strait, 79°18´N 100°21´E, i/b "V. Rusanov", 20.08.1932, 2 spec.	V.L. Vagin and N.N. Kondakov
	[*Gymnocanthus tricuspis*]	
Esipov 1952	At Cape Chelyuskin (Taymyr), 77°41´N 104°15´E, depth 11–13 m, 8.09.1933, i/b "A. Sibiryakov", st. 28, ground–pebbles, algae; 4 spec.	V.L. Vagin and G.P. Gorbunov
30646, 32842	At Cape Chelyuskin (Taymyr), 77°41´N 104°15´E, depth 10 m, 08.09.1933, i/b "A. Sibiryakov", st. 30, ground–stones, rocks; 5 and 2 spec.	G.P. Gorbunov
	Family Liparidae	
	4. *Liparis tunicatus*	
50719	Severnaya Zemlya, Sredniy I., at the Polar station "Golomyanniy", 79°30´N 90°40´E, depth 7–12 m, 26.04.1982, diver's sample, ground–pebbles, stone; 1 spec.	V.G. Averintsev
32674	To the east of Bolshevik I., 78°40´N 106°30´E, 09.09.1913, i/s "Taymyr", st. 87, depth 7 m, ground-silt, 4 spec.	L.M. Starokadomsky
34040	Vilkitsky Strait, Cape Chelyuskin (Taymyr), 77°41´N 104°15´E, depth 11–13 m, 08.09.1933, i/b "A. Sibiryakov", st. 28, ground-pebbles, algae; 2 spec.	G.P. Gorbunov
Esipov 1952	Same data; 1 spec. [as *L. liparis*].	V.L. Vagin and G.P. Gorbunov
32673	Taymyr, 76°59´N 108°33´E, 16(29).08.1913, i/b "Taymyr", 1 spec.	L.M. Starokadomsky
	5. *Liparis* cf. *fabricii*	
Esipov 1952	Vilkitsky Strait, 78°11´N 105°38´E, depth 177 m, 6.09.1932, i/b "V. Rusanov", st. 23, yellow clay and sandy silt, t –0.94°C, S 34.44 psu, 1 spec. [as *L. koefoedi*].	V.L. Vagin and N.N. Kondakov
32011	South of October Revolution I., 78°43´N 97°55´E, depth 78.5 m, 1948, i/b "F. Litke", st. 114, 2 spec.	V.L. Vagin
32021	East of Bolshevik I., 78°34´N 105°34´E, depth 140 m, 01.09.1948, i/b "F. Litke", st. 140, 3 spec.	V.L. Vagin
32026	Shokalsky Strait, 78°53´N 100°15´E, depth 250 m, 27.08.1948, i/b "F. Litke", st. 120, 1 spec.	V.L.Vagin
32648	Vilkitsky Strait, off Taymyr coast, 77°21.1´N 103°47´E, 12.08.1937, i/b "Sadko", 1 spec.	G.P. Gorbunov
56679	Bolshevik I., Akhmatova Bay, 79°02.91´N 103°0.81´E, 03.09.2019, R/V "Prof. Molchanov", st. 40, diver's sample, 1 spec.	V.V. Sokolov
	6. *Careproctus* sp.	
Esipov 1952	Vilkitsky Strait, 78°02´N 105°24´E, depth 173 m, 5.09.1932, i/b "V. Rusanov", st. 22, yellow clay and sandy silt, t –0.64°C, S 34.52 psu, 1 spec. [as *C. reinhardti* (Krøyer 1862)].	V.L. Vagin and N.N. Kondakov
32060	West of Komsomolets I., 80°30´N 90°03´E, 1948, depth 174 m, i/b "F. Litke", ground-silt	V.L. Vagin
	Family Zoarcidae	
	7. *Gymnelus knipowitschi*	
Gorbunov 1946; Esipov 1952	North of Shokalsky Strait, 79°15.5´N 100°04´E, depth 145 m, 20.08.1932, i/s "V. Rusanov", st. 18, ground-stones, gray silt, sponges, t –1.69°C, S 34.47 psu, 17 spec. [as *G. viridis*]	V.L. Vagin and N.N. Kondakov
56680	At the eastern end of Wiese I., 79°34.97´N 77°39.76´E, depth 38 m, 22.08.2019, R/V "Prof. Molchanov", st. 1, grab "Ocean-0.1", 1 spec.	A.S. Solomatov, S.A. Kovalyov, V.L. Syomin, A.B. Basin and V.A. Spiridonov

Table 1 (End)

References or ZIN Nos	Locations	Collectors
56681	Bolshevik I., Mikoyan I., at Dva Tovarischa I., 79°16.38´N 102°10.98´E, depth 4–18 m, 01.09.2019, R/V "Prof. Molchanov", st. 34, diver's sample, 1 spec.	V.L. Syomin, S.A. Kovalyov, V.V. Sokolov, A.I. Tereschuk and V.A. Spiridonov
	8. *Lycodes pallidus*	
32033	The north of the Shokalsky Strait, 78°39´N 106°06´E, depth 220 m, 31.08.1948, i/b "F. Litke", st. 139, 2 juv.	V.L. Vagin
32037	The north of the Shokalsky Strait, 79°30´N 101°47´E, depth 234 m, 27.08.1948, i/b "F. Litke", st. 126, brown silt and sand, 1 spec.	V.L. Vagin
32038	The south-west of the Vilkiysky Strait, 77°28´N 101°47´E, depth 105 m, 09.09.1948, i/b "F. Litke", st. 180, ground-gray sandy silt, nodules, 2 spec.	V.L.Vagin
36174	To the north-east of Severnaya Zemlya, 81°24´N 96°54´E, depth 230 m, 16.08.1932, i/b "A. Sibiryakov", st. IX, Sigsbee trawl, ground-silt, sand; 8 spec.	L.O. Retovsky
	[*Lycodes seminudus*]	
32043	To the west of Severnaya Zemlya, 80°17´N 85°36´E, depth 292 m, 01.10.1948, i/b "F. Litke", st. 186, 1 spec.	V.L. Vagin
32745	To the north of the Arctic Cape (Komsomolets I.), 81°31´N 94°38´E, depth 460 m, 12.09.1935, i/b "Sadko", st. 57/97, ground-silt, sand; t −0.2°C, 4 spec.	G.P. Gorbunov
36173	To the north-east of Komsomolets I., 81°24´N 96°54´E, depth 230 m, 16.08.1932, i/b "A. Sibiryakov", st. IX, Sigsbee trawl, ground-silt, sand; 3 spec.	L.O. Retovsky
	[*Lycodes eudipleurostictus*]	
Esipov 1952	To the north-west of the Komsomolets I. [ca. 81°32.9´N 83°05.5´E], depth 490 m, i/b "Sadko", 9.09.1935, ground-silty sand; t −0.20°C, S 34.78 psu, 4 spec.	G.P. Gorbunov
	Family Gasterosteidae	
	9. *Gasterosteus aculeatus*	
48974	Southwestern coast of the October Revolution I., 24.09.1985, area of the Ozyornaya River, near the station of Arctic and Antarctic institute; dropped by a kittiwake *Rissa tridactyla*, 2 spec.	M.V. Gavrilo
	Freshwater fishes	
	Family Salmonidae	
	10. *Salvelinus alpinus*	
48989	Bolshevik I., Lake Tverdoe (at the base of the peninsula between the Shokalsky Strait and Mikoyan Bay), depth 8 m, 01.05.1988, 1 spec.; donated to ZIN by M.V. Gavrilo.	S.P. Polyakov
56467	Bolshevik I., Lake Tverdoe, 17.06.2018, 8 spec. *TL* 147–205 mm; donated to ZIN by M.V. Gavrilo.	S.V. Golubev

Abbreviations: S – salinity; spec. – specimen(s); t – bottom temperature. The bracketed species were recorded adjacent to Severnaya Zemlya and one can expect them to occur in the waters of the archipelago.

kelp *Laminaria sakharina* [=*Saccharina latissima* (Linnaeus) Lane, Mayes, Druehl et Saunders, 2006] (Averintsev 1989).

Family Liparidae

2.4. *Liparis tunicatus* – Arctic snailfish

The species was found by a diver at the Sredniy I., on a transect from the coast to a depth of 20 m, in a biocenosis of sugar kelp: "Occasionally, red-colored *L. tunicatus* adhering to the [*Saccharina*] tallome appear" (Averintsev 1989: 152). The species identification was confirmed on the basis of one of the specimens received from this diver (ZIN No. 50719) (Chernova 1991). The ZIN collections contain also *L. tunicatus* sampled east of the Bolshevik I. and off the Cape Chelyuskin (Vilkitsky Strait, the coast of the Taymyr Peninsula) (Table 1).

The Arctic snailfish is widely distributed on shallow-water shelves (Esipov 1952 [under the name *L. liparis* (Linnaeus, 1766)]; Chernova 1991; Chernova in Dolgov et al. 2018). It may be common in the

Fig. 7. Black-bellied snailfish *Liparis* cf. *fabricii*, Bolshevik Island (ZIN No. 56679, *TL* 102 mm).

waters of Severnaya Zemlya since it is often found in the shallows of another high-latitude archipelago, Franz Josef Land (Chernova et al 2014).

2.5. *Liparis* cf. *fabricii* – black-bellied (or gelatinous) snailfish (Fig. 7).

This species complex, which requires revision, differs from other *Liparis* in the black peritoneum. A specimen was recorded from the Vilkitsky Strait at a depth of 177 m at a temperature of −0.94°C and salinity 34.44 psu (Esipov 1952 [as *L. koefoedi* Parr, 1931]). The species had been previously found near Domashniy I.; according to N.P. Demme, several "snailfishes" 10–15 cm long were caught in shallow water among stones in September 1932 (Burmakin 1957). Perhaps some of them may belong to the previous species. A mature female *SL* 86 mm was caught by a diver of expedition O2A2-2019 in Akhmatov Bay, Bolshevik I. (ZIN No. 56679).

Description. The head length (*c*) is large (31.6% *SL*), low (77% *c*) and wide (77% *c*). The posterior nostril is in the form of a slit pore, equal in diameter to the anterior tubular nostril. Eye 23.9% *c*, interorbital 37.5% *c*. The mouth reaching the vertical of the anterior margin of the eye. The gill opening reaches the level of the fifth pectoral ray. Pores 2–6–7–2, the chin pores are drawn together. Vertebrae 52 (12+40). *D* 47, *A* 40. *C* 1+4/5+1. At the beginning of the dorsal fin, 11 rays are completely immersed in the gelatinous tissue, of which the anterior 5 are very thin; normally developed *D* rays start above the beginning of *A* (above the 1st caudal vertebra). *P* 35 (28 in the upper lobe, counting the shortest ray of the notch, and 7 in the lower lobe). Disk 12.8% *SL*. The anus opens closer to the disk than to the beginning of *A*. The skin is naked, translucent, on the caudal part there are 5 wide oblique stripes overlapping the fins. A black stripe runs along the base of *D* under the skin. Peritoneum covered with dense pigmentation on a light background. Ovarian eggs are about 2 mm in diameter. This coastal form of black-bellied snailfish is apparently a common inhabitant of the shallow waters of the Arctic islands – in the area of Franz Josef Land, specimens (including a mature male) were recorded at depths of 10–25 m (Chernova et al. 2014, fig. 12A–D).

The ZIN collection contains *L.* cf. *fabricii* from the waters of the Bolshevik I. and October Revolution I., the Shokalsky and Vilkitsky straits, from depths of 78.5–250 m, collected by G.P. Gorbunov ("Sadko", 1937) and by V.L. Vagin ("F. Litke", 1948) (Table 1). Other captures of this snailfish (Borkin et al. 2008; Smirnova and Karamushko 2015; Dolgov et al. 2018) were made not in the area of Severnaya Zemlya.

2.6. *Careproctus* sp. – tadpoles

In the area of Severnaya Zemlya, *Careproctus* Krøyer, 1862 specimens are indicated at depths of 173–234 m in the Vilkitsky and Shokalsky straits, to the west of the Komsomolets I. and east of the October Revolution I. (Esipov 1952; Chernova 1991). Species identification requires clarification, since recently new species of this genus have been described from the Kara Sea.

Fig. 8. Knipowich eelpout *Gymnelus knipowitschi*, caught to the east of the Wiese Island (ZIN No. 56680, female *TL* 101 mm).

Family Zoarcidae

2.7. *Gymnelus knipowitschi* Chernova, 1999 – Knipowich's eelpout (Fig. 8).

The species (under the name *G. viridis* (Fabricius 1780), fish doctor) was recorded in the north of the Shokalsky Strait at a depth of 145 m (bottom temperature –1.69°C, salinity 34.47 psu) (Gorbunov 1946; Esipov 1952).

Two specimens were caught by Expedition O2A2-2019 in 2 distant areas, to the east of the Wiese I. at a depth of 38 m (ZIN No. 56680, female *TL* 101 mm) and in Mikoyan Bay at depths of 4–18 m (ZIN No. 56681, male *TL* 134 mm).

Description. Dorsal fin begins above the middle to posterior third of the pectoral fin. Vertebrae 92 (19+73) and 89 (19+70), *D* 87 (85), *A* 74 (70), the first ray of *D* in both is between vertebrae 3 and 4, free interneuralia 0 (1). *P* 12 (10). Pores in both: infraorbital 6, nasal 2, temporal 1+3, preoperculo-mandibular 7, in the occipital commissure 1+1. The male can be distinguished by the blackish margin of the anal fin and the longer upper jaw (extending beyond the posterior edge of the eye). The color is more or less monochromatic, with indistinct traces of transverse stripes (there are at least 10 of them). In the female, the anal fin is light; the upper jaw does not reach the posterior edge of the eye. The top of the head and snout are dark gray, sharply delimited from the light lower part of the head. The lower side up to the midline of the body is yellowish. Above, on the sides, there are 12 blackish spots, clearly delimited by the midline of the body and extending onto the dorsal fin.

The ZIN collection contains specimens of *G. knipowitschi* caught to the southwest (ZIN No. 30682) and southeast (ZIN No. 32076) of the archipelago (not included in Table 1).

In field identification, one of the two specimens was noted as *Lycodes*. This could mean that the "eelpouts" caught by a dredge in shallow waters near Domashniy I. in September 1932 (about 20 specimens 5–10 cm long) (Burmakin 1957) could belong to *Gymnelus* Reinhardt, 1834. This assumption is supported by the fact that, in the ZIN materials, all *Lycodes* from the Severnaya Zemlya were caught, not in shallow waters as *Gymnelus*, but at depths of more than 100 m.

2.8. *Lycodes pallidus* – Pale eelpout

The species was caught at depths from 105 to 348 m at the north of the Shokalsky Strait, at the southwest of the Vilkiysky Strait and to the north-east of Severnaya Zemlya (Table 1).

[Longear eelpout *L. seminudus* Reinhardt, 1837] was caught at depths of 230–460 m, in the Kara Sea west of Severnaya Zemlya, and to the north of the Arctic Cape (Komsomolets I.), the northernmost tip of the archipelago from icebreakers "A. Sibiryakov" (1932), "Sadko" (1935) and "F. Litke" (1948).

[The doubleline eelpout *Lycodes eudipleurostictus* Jensen, 1902] was caught to the northwest of the Komsomolets I. at a depth of 490 m ("Sadko", 1935).

Other captures of eelpouts (Borkin et al. 2008; Dolgov et al. 2018; Smirnova et al. 2019) were made not in the area of Severnaya Zemlya. Further research will likely discover these eelpout species in the deep-water straits of Severnaya Zemlya.

2.9. *Gasterosteus aculeatus* – three-spined stickleback (Fig. 9).

Two specimens *TL* 66 and 54 mm (ZIN No. 48974), found in 1985 on the southwestern coast of the October Revolution Island (near the Ozyornaya River), were caught by a sea bird.

Description. *D* III 14, A I 10, P 10, V I 1.Vertebrae 31 (14+16) and 32 (15+16). Caudal fin rays

Fig. 9. Three-spined stickleback *Gasterosteus aculeatus*, October Revolution Island (ZIN No. 48974, *TL* 66 mm).

12(6/6) on hypurals, 7 upper and 6 lower short unbranched rays. Lateral plates on body 30, the last 4 of them form a lateral keel on the caudal peduncle.

The specimens, with a large number of lateral plates and a keel on the caudal peduncle, should be attributed to the "trachurus" morph, characteristic of anadromous populations that spend at least part of their life in sea waters (Zyuganov 1991). The fish were dropped by a kittiwake. These birds forage in the sea, moving away from the coast to a distance of 5–40 (sometimes up to 100) km (Gavrilo 2020). The diet is based on small pelagic fish, which they catch from shallow (up to 0.5 m) depths. Thus, it is very likely that the three-spined stickleback was caught in the Kara Sea near Severnaya Zemlya and not brought from the mainland that is at a greater distance.

This is the first record of *G. aculeatus* on the eastern edge of the Kara Sea. Previously, the easternmost record of this amphiboreal species in the Atlantic sector of its range was "Novaja Zemlya (Tjagin)" (Knipowitsch 1897, and subsequent authors). Attribution showed that this place is located in the west of the South Island of the Novaya Zemlya archipelago, in the Malye Karmakuli (72°22´24″N 52°43´00″E), where E.A. Tjagin, Lieutenant of the Naval Navigation Corps, on behalf of the Hydrographic Department, founded in 1877 a polar station, which still exists. Recently, the three-spined stickleback was recorded from the east (the Kara Sea) side of the same island of Novaya Zemlya, in 2 freshwater lakes off the coast of Ambrosimov Bay (Bolshakova and Bolshakov 2018). Another record was in Baydaratskaya Bay (offshore), i.e. at the western limits of the Kara Sea (Dolgov et al. 2018). Three-spined stickleback has not been found in other coastal areas of the Kara Sea, including the well-studied Ob and Yenissei estuaries (Ponomareva 1949; Esipov 1952; Matkovsky 2006; Borkin et al. 2008; Dolgov et al. 2018). The species is absent along the whole mainland Siberian coast (Popov 2013). In the Pacific part of the range, the three-spined stickleback begins to be found only in the Bering Strait area (Chereshnev 2008). The absence of the three-spined stickleback along the Siberian coast and mainland suggests that this species could have penetrated into the waters of Severnaya Zemlya from the west side of the Kara Sea. And that was before the climate warming (in 1985).

Freshwater fishes

2.10. *Salvelinus alpinus* (Linnaeus, 1758) – Arctic charr (or Arctic char).

The species was recorded on Severnaya Zemlya in the list of vertebrates living on the Bolshevik and October Revolution islands (no exact locations) (Bolshiyanov and Makeev 1995). On the Bolshevik I., in a small, isolated, unnamed lake in its southern part, there are 2 morphs or "forms" of charr: large-sized (forked length is 35.2–50.1 cm) and dwarf one (19.6–21.4 cm) (Alekseev et al. 2003). According to the reports of geologists, charr lives on the western and northern parts of the Bolshevik I. in lakes Studenoe and Spartakovskoe, and on the October Revolution I. in Lake Fjordovoe (Alekseev et al. 2003).

The ZIN collections contain specimens of Arctic charr caught in Tverdoye, another lake on the Bolshevik Island. There are samples of different years from this reservoir, received in 1988 (ZIN No. 48989) and 2018 (ZIN No. 56467). The species is likely to be found in the other lakes of the archipelago.

Lacustrine and anadromous forms of the Arctic charr are distributed circum-continentally in the Arctic. The fish inhabits freshwaters of Spitsbergen (Svenning et al. 2007; Wietrzyk-Pełka and Węgrzyn 2020), but is not found on the high-latitude Franz Josef Land Archipelago. The species occurs on many islands located along the Arctic coasts of the Eurasian mainland: Kolguev, Novaya Zemlya (south of 76.2° N), Vaigach, Kolosovykh (Skerries of Minin), Bolshoy Begichev, Preobrazheniya, and some of the Novosibirsk Islands (Bolshoi Lyakhovskoy and Kotelniy) (Burmakin 1957; Alekseev et al. 2003).

The ZIN collections contain specimens from fresh waters of Novaya Zemlya (Nos. 8944 and 8945, collected by K. von Baer in 1882; Nos. 8997, 23641, 30177 and 30650), as well as from Kotelniy I. (Nos. 8960, 9617 and 9929, collected by E. von Toll in 1885 and 1887).

CONCLUSION

As revealed by expedition O2A2-2019, the marine biotopes of Severnaya Zemlya are diverse (Gavrilo et al. 2019). There are bays of different types: classic fjords, carved by glacial processes, fjords with relatively shallow underwater sills at the entrance (such as Akhmatova Bay in Bolshevik I. and Uzlovaya Bay in Bolshevik I.), deep glacial fjords (for example, Matusevich fjord on October Revolution I. with a depth of 250 m), or shallow bays with extensive river runoff (Panfilovtsev and Mikoyan bays). Some of the straits of Severnaya Zemlya are relatively shallow – Shokalsky (200–250 m) and Yuniy (220 m) straits; some are deep, such as the Krasnoy Armii Strait (460 m). The variability of biotopes near the archipelago determines the possibility of a high biological diversity. This has been confirmed by previous, although scarce, studies. At least 50 species were identified in zooplankton samples from the Shokalsky and Vilkitsky straits; among them, there are representatives of several groups: 1) species of the Central Arctic Ocean (CAO); 2) species associated with the transformed Atlantic waters coming from the CAO; 3) brackish-water species associated with waters of continental runoff; 4) arctic and mainly arctic species, that are widespread in the northern seas (Khmyznikova 1937; Virketis 1943). In the benthic samples from the Shokalsky Strait, there are representatives of several faunistic complexes: 1) high-arctic sublittoral-bathyal species; 2) high-arctic bathyal-abyssal species associated with the Atlantic waters; 3) low-arctic boreal species; 4) arctic species (Gorbunov 1946). A scuba-dive survey performed near Sredniy I., on a short transect from the coastline to a depth of 20 m, showed the presence of three biocenoses (Averintsev 1989). Under the lower surface of fast ice, there is a cryopelagic biocenosis (although poor in terms of species richness) consisting of diatoms, some macrophytes and *Apherusa glacialis* (Hansen, 1888) (Amphipoda). At depths of up to 15 m, a biocenosis with the dominance of sugar kelp *Saccharina latissima* has developed, which includes 3–4 species of red and brown algae, sea urchins, buccinid molluscs and the predatory gastropod *Natica* Scopoli, 1777, ophiurans, bryozoans, mysids, sponges, nudibranchs and ascidians. Deeper than 15 m, there is a biocenosis composed of the red algae *Phycodrys rubens* (Linnaeus) Batters, 1902 (Rhodophyta), *Hormatia nodosa* (Fabricius, 1780) (Actiniaria), *Strongylocentrotus droebachiensis* (O.F. Müller, 1776) (Echinacea), with a large number of buccinids, bryozoans and red shrimps (Averintsev 1989). The preliminary results of expedition O2A2-2019 also showed the richness of marine life in the region of Severnaya Zemlya and the distinct patterns of its distribution (Gavrilo et al. 2019, 2020).

Against this background, the ichthyofauna of the archipelago seems to be species poor. However, this is due to the fact, that no targeted work was carried out using ichthyological fishing gears. According to the data presented here, the following species are recorded: *Boreogadus saida* (Gadidae); *Artediellus scaber* and *Icelus bicornis* (Cottidae); *Liparis tunicatus*, *L*. cf. *fabricii* and *Careproctus* sp. (Liparidae); *Gymnelus knipowitschi* and *Lycodes pallidus* (Zoarcidae), *Gasterosteus aculeatus* (Gasterosteidae) and *Salvelinus alpinus* (Salmonidae). The presence of *Gymnocanthus tricuspis* (Cottidae) and at least two more *Lycodes* species (Zoarcidae) is also probable. With further research of the archipelago, one can expect to find many more species. One group can represent the endemic Arctic fauna, inhabiting the adjacent shelf of the Kara Sea and the Laptev Sea. They may include, for example, the glacial (or ice) cod *Arctogadus glacialis* (Peters, 1874), Deriugin's spiny lumpsucker *Eumicrotremus derjugini* Popov, 1926, the Arctic alligatorfish *Aspidophoroides olrikii* (Lütken, 1877), the polar eelpout *Lycodes polaris* (Sabine, 1824) and others. To the west of the archipelago, eastern surface branches of the Ob-Yenisey current carry relatively warm and freshened waters of the Siberian rivers to the north; in certain years they can approach Severnaya Zemlya (Laktionov 1936; Kubryakov et al. 2016; Kara Sea 2021). The distribution of an estuarine complex can be associated with these currents; such as omul *Coregonus autumnalis* (Pallas, 1776), *Eleginus* sp., ninespine stickleback *Pungitius pungitius* (Linnaeus, 1758) and smelts *Osmerus* (Linnaeus) Lacepède, 1804 can arrive at Severnaya Zemlya. Transformed water masses of Atlantic origin pass at the depths along the slope of the Voronin Trough west of the Pioneer and Komsomolets islands, and along the continental slope east of the archipelago; these waters enter the Shokalsky and Vilkitsky straits from the east (Laktionov 1936; Bluhm et al. 2020; Kara Sea 2021). A specific fish complex associated with these water masses may include, for example, the Greenland shark *Somniosus microcephalus* Bloch et Schneider, 1801, Atlantic hookear sculpin *Artediellus atlanticus* Jordan et Evermann, 1898. Upon further investigation of Severnaya Zemlya, one can expect, therefore, the presence of a rather diverse fish fauna, including representatives of at least 3 fish complexes of different origin and composition. In conclusion, it should be noted that Severnaya Zemlya is an important location for mass spawning of polar cod – a key species in Arctic marine ecosystems.

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