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MASTER DISSERTATION

THE INFESTATION OF SOME COMMERCIALLY IMPORTANT SPECIES OF CARP FISH WITH METACERCARIAE *OPISTHORCHIS FELINEUS* IN THE MIDDLE OB BASIN

For qualification of master degree of biology
According to the basic educational program of masters
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МАГИСТЕРСКАЯ ДИССЕРТАЦИЯ

ЗАРАЖЕННОСТЬ ЗНАЧИМЫХ ПРОМЫСЛОВЫХ ВИДОВ КАРПОВЫХ РЫБ МЕТАЦЕРКАРИЯМИ *OPISTHORCHIS FELINEUS* В БАССЕЙНЕ СРЕДНЕЙ ОБИ

по основной образовательной программе подготовки магистра
направление подготовки 06.04.01 – Биология

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АННОТАЦИЯ

Актуальность магистерской диссертации. Томская область (бассейн Средней Оби) включена в зону крупнейшего Обь–Иртышского очага описторхоза, к которому относятся река Томь и ее притоки [Ильинских и др. 2007; Сыскова и др. 2001]. По данным ФБУЗ «Центра гигиены и эпидемиологии» за последнее десятилетие в Томской области наблюдается снижение интенсивного показателя зараженности населения описторхозом (с 239.3 до 130.6 на 100 тыс. нас.), однако, показатели остаются высокими. В период с 2017 по 2019 гг. средний интенсивный показатель зараженности на 100 тыс. населения описторхозом по Томской области выше у жителей, проживающих в районах, таких как Александровский (607), Каргасокский (484), Тегульдетский (368), Асиновский (239), Колпашевский (121), Томский (114).

Заражение человека и плотоядных животных происходит только при употреблении в пищу сырой (талой, мороженой, слабопросоленной) и недожаренной или непроваренной рыбы карповых пород, зараженной личинками *Opisthorchis felineus* (Rivolta, 1884).

В настоящее время в водоемах Средней Оби насчитывается около 13 видов карповых рыб [Romanov et al., 2017]. В период с 2012 по 2018гг. наиболее доминирующими видами по вылову из р. Оби являются плотва (277т), язь (275т), лещ (266 т). Показатели вылова карася (68.2т) и ельца (60.3т) не столь значительные, однако тоже довольно высокие. Данные виды карповых рыб являются *объектами нашего исследования*. Помимо промысловой ценности, согласно исследованиям предыдущих лет, они могут быть носителями метацеркарий трематоды *Opisthorchis felineus*, являющейся, в свою очередь, *предметом нашего исследования*. Изучение второго промежуточного хозяина и его зараженность метацеркариями *O. felineus* играет огромную роль в профилактике описторхоза, поэтому, *целью нашей магистерской работы* является изучение зараженности метацеркариями трематод основных промысловых видов карповых рыб в реках бассейна Средней Оби.

В связи с поставленной целью сформулированы *следующие задачи*:

1. Оценить эпидемиологическую ситуацию по описторхозу в Томской области;

2. Проанализировать промысловые запасы карповых рыб в Томской области, таких как *Leuciscus idus* (язь), *Leuciscus leuciscus* (елец), *Rutilus rutilus* (плотва), *Abramis brama* (лещ), *Carassius gibelio* (карась);

3. Определить количественные показатели (экстенсивность, интенсивность и индекс обилия) зараженности основных промысловых видов карповых рыб метацеркариями *Opisthorchis felineus* в бассейне Средней Оби.

Весь полученный материал был подвергнут общебиологическому анализу, определялся рост (L), вес (W) и возраст рыбы по чешуе. Все данные заносились в специальный журнал, где отмечались также дата, место добычи рыбы. Затем, приступали к проведению паразитологического анализа. Для определения зараженности мышц рыб метацеркариями был использован *метод полного паразитологического вскрытия*, при котором мышцы просматривались полностью. Для выявления зараженности рыбы метацеркариями кошачьей двуустки применяли *компрессорный метод*. Проведена математическая обработка данных. Определялись такие показатели, как экстенсивность, интенсивность и индекс обилия. Для определения зависимости, применялись статистические тесты корреляции Spearman и Kendal Tests (при $p < 0.001$). Проверка на нормальность распределения полученной выборки определялась с помощью Shapiro–Wilk test (при $p < 0.05$).

Средняя экстенсивность инвазии (ЭИ) язя составила 94.5% (от 86.2 до 100%), средняя интенсивность инвазии (ИИ) – 49.3 экз. на одну особь (от 2 до 190 метацеркариев). Средняя ЭИ самцов – 97%, самок – 85% (ИИ 49.6 и 47.7 экз. на одну особь соответственно). У язей в возрасте 2+ ИИ – 20.5; в возрасте 3+ – 39.7; у особей в возрасте 4+ – 49.7; 5+ – 46; 6+ – 49.5;7+ – 70; 8+ – 57 экз. на одну особь.

Средняя ЭИ ельца из р. Томи – 85% (от 66 до 95.4%). Средняя ИИ составила – 12.7 метацеркариев на одну особь (от 1 и до 137). Средняя ЭИ самцов – 83%, самок – 90%. Средняя ИИ у самца 1+ – 13.25, у самки – 3; у самца в возрасте 2+ – 4.81, у самки— 14.5; у самца в возрасте 3+ – 11.95, у самок – 10.3; у самца в возрасте 4+ – 11.6, у самок – 17.8; у самца в возрасте 5+ – 32.8, у самки – 13.75; у самца в возрасте 6+ – 55 метацеркарий на одну особь.

Была выявлена зависимость зараженности ельца от их возраста (p <0.001), также от их линейно–весовых показателей (p <0.001). На примере ельцов, было показано, что с возрастом и увеличением линейно–весовых показателей происходит увеличение показателей интенсивности инвазии рыб, что связано с накоплением паразита *Opisthorchis felineus* в мышцах.

Средняя ЭИ леща составила 2.05%, средняя ИИ – 2 экз. на особь. Средняя ЭИ плотвы составила 1.23%, средняя ИИ – 4 экз. на особь. За период нашего исследования зараженных карасей не было обнаружено.

Таким образом, промысловые рыбы язь и елец остаются основными носителями метацеркарий описторхид в бассейне Средней Оби. С возрастом и увеличением размеров этих рыб ИИ увеличивается. Самки ельцов заражены больше, чем самцы. ЭИ леща и плотвы крайне низкие. Зараженных карасей не обнаружено.

Научная новизна. Впервые в бассейне Средней Оби проведено изучение зараженности основных промысловых карповых рыб. Установлено, что язь, являющийся доминирующим в промысле, является основным носителем метацеркарий *Opisthorchis felineus* и представляет наибольшую угрозу для населения. Елец имеет незначительное промысловое значение, однако крайне высокие показатели зараженности. Остальные промысловые рыбы не представляют значительной угрозы, поскольку, имеют крайне низкие показатели зараженности.

Научно–практическая значимость. Результаты исследования представляют научно–практическую значимость для обеспечения безопасности населения от заражения описторхозом. Основные результаты исследования могут найти применение при обработке данных будущих исследований.

Результаты исследования были апробированы в материалах студенческой конференции «Старт в науку».

Содержание магистерской диссертации. Диссертация состоит из введения, заключения и 5 глав, изложена на 75 страницах, включая список литературы из 84 наименований, включает 8 таблиц и 47 рисунков.

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INTRODUCTION

Fishing is a significant type of industry in Western Siberia. One of the areas that has great commercial opportunities is Ob–Irtysh basin, which is known by being the largest outbreak with a high prevalence of the disease Opisthorchiasis. This disease is widely distributed, especially in the areas along the rivers, tributaries, and lakes of the Ob–Irtysh basin.

Humans and other mammals act as a natural definitive host, which are infested after eating raw, freshwater, or undercooked, unsalted fish with metacercariae *Opisthorchis felineus* (OF) (Rivolta, 1884).

Infestation caused with species within the genera Opisthorchis manifests itself in abdominal pain, fever and weight loss [Traverso et al., 2012; Pozio et al., 2013; Pornruseetairatn et al., 2016]. Chronic opisthorchid infestations cause injuries to the common bile duct, subsequently leading to cholangitis, choledocholithiasis, pancreatitis and cholangiocarcinomatosis [Watanapa & Watanapa, 2002; Sithithaworn & Haswell–Elkins, 2003; Chai et al., 2005; Rim, 2005; Toledo et al., 2012].

Studying the secondary intermediate host and its infestation plays an enormous role in the prophylaxis of disease Opisthorchiasis. The formation of the outbreak of this disease depends on the conditions of the infesting of the primary and secondary intermediate hosts.

Tomsk Region is included in the Ob–Irtysh basin, with the river Tom and its tributaries [Ильинских и др. 2007; Сыскова и др. 2001]. Currently, there are thirteen species of carp fish that inhabit the Ob-Irtysh basin, of which five are commercially significant species of carp fish [Romanov et al., 2017]. In addition to their commercial value, they act as a second intermediate host, harbouring the metacercariae of trematode *Opisthorchis felineus* in the muscles.

The results from the earlier investigation showed that the infestation of commercial species of carp fish could reach 100%, and that is why the most important aspect of our research was to study fish infestation. Over the last few years, for some reason the infestation rate has increased among adults, as well as among children. Currently, material informing people about how to stay safe from this disease has become less available. In addition, fish that are usually delivered to the market are not being checked properly. Knowledge about the infestation rate identified in fish is one of the main ways to control the prevalence of the disease.

The purpose of our research was to detect the infested commercial species of carp fish in the Middle Ob basin.

For achieving this purpose, some objectives have been set:

1. To estimate epidemiology of people living in Tomsk oblast.

2. To analyze the commercial stocks of carp fish such as *Leuciscus idus* (ide), *Leuciscus leuciscus* (dace), *Rutilus rutilus* (roach), *Abramis brama* (bream), *Carassius gibelio* (crucian) in the area of Tomsk oblast.

3. To identify the quantitative indicators of infested species of carp fish with metacercariae *Opisthorchis felineus*, such as the prevalence and the intensity of infestation, and abundance index in the Middle Ob basin.

1 Epidemiology of population infested with Opisthorchiasis in Tomsk oblast

Opisthorchiasis is the helminthic disease caused by trematode *Opisthorchis felineus*, which is commonly known as a cat liver fluke that has a devastating effect on the human hepatobiliary system and pancreas [Яблоков, 1979]. Opisthorchiasis is a long–term and chronic disease, with some progression leading to liver and biliary duct cancers [Балашева и др., 1990]. This disease is recognized as a pathologically and economically significant food–borne disease.

According to some investigation, an estimated 600–750 million people worldwide are being infested by trematode *Opisthorchis felineus* [Marcos et al., 2008; Petney et al., 2013; Ogorodova et al., 2015]. The cat liver fluke is also endemic in areas such as Siberia, mainly between the river Ob in the east, and Poland and the river Danube delta in the west. The basin of the river Dnieper and its tributaries in Ukraine is endemic of Opisthorchiasis [Kumar, 1999]. This disease is reported to be the largest hotbed in the Ob–Irtysh basin, including its rivers such as the Ob, Irtysh, Ural, Volga, Kamy, Don, Dnieper, Northern Dvina and Biryusa [Федорова и др., 2016]. Based on literature about the Ob–Irtysh basin, with its rivers and tributaries, the prevalence of the disease Opisthorchiasis could be reaching 90%. Usually in some cities located by this basin, such as Tomsk, Tymen, and other areas along the river Ob and its tributaries, the prevalence of infested people could be higher.

Transmission to human beings and other mammals, such as cats, dogs, and others, can occur through the consumption of undercooked or raw, freshwater carp fish containing different numbers of metacercariae *Opisthorchis felineus*.

Based on the given data from the Hygiene and Epidemiology Center in Tomsk Oblast concerning infested people living in the Russian Federation (shown in Figure 1), from 2014 the number of infested people was annually decreasing from 25545 infested people (17.51 cases per 100 thousand people) with the disease Opisthorchiasis to 18755 infested people (12.79 cases per 100 thousand people) in 2017. However, there was a slight increase in 2018, and the number of infested people who had Opisthorchiasis was 19137 (12.99 cases per 100 thousand people).

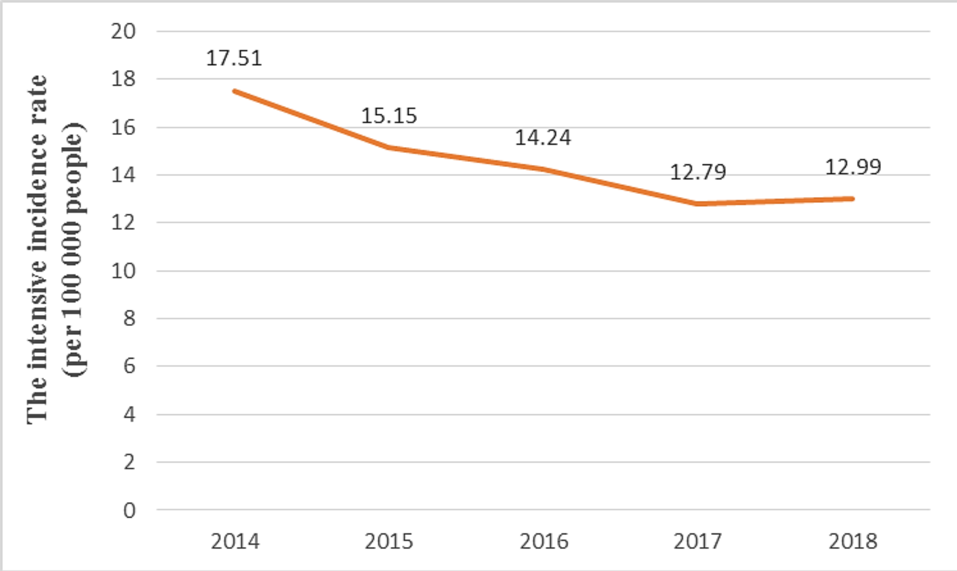

Figure 1 – Incidence rate of the disease Opisthorchiasis among adults in the Russian Federation from 2014 to 2019

Analyzing the children infested with the disease Opisthorchiasis revealed the same trend as was shown previously, regarding Opisthorchiasis detected among adults. In 2014, child–infestation was 2388, meaning 8.67 cases per 100 thousand people. This incidence rate gradually decreased in 2018, when there were 1818 cases of child–infestation, which meant 6.54 cases found per 100 thousand people (Figure 2).

According to Zavoikyn's opinion, territory of the Tomsk Oblast is a hyper–infested area [Завойкин и др., 1986; Завойкин и др., 1991; Завойкин и др., 1994]. From 2014 to 2018, the prevalence of Opisthorchiasis was almost 7% (6.53%) in Tomsk oblast, recorded from the general percentage of infested people living in the Russian Federation (93.47% was distributed to other areas of Russia).

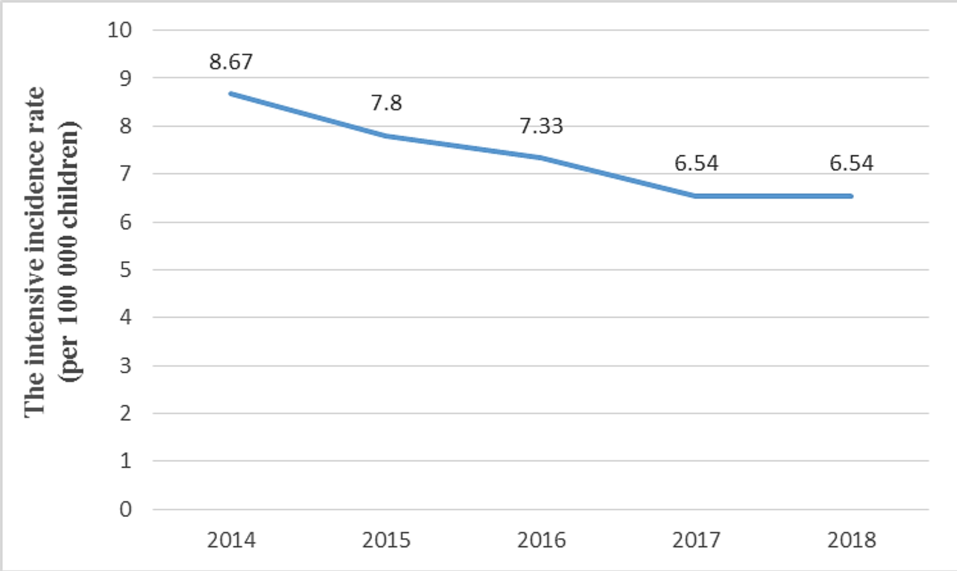

Figure 2 – Incidence rate of the disease Opisthorchiasis among children in the Russian Federation from 2014 to 2019

The graph below also shows the dynamics of Opisthorchiasis infestation found per 100 thousand people based on the given data from the hygiene and epidemiology center in Tomsk Oblast. The incidence rate in 2004 was 645.3 (or 6007 infested people), and this then gradually reduced to 104.7 (or 1129 infested people) in 2018. Consequently, the trend was that the incidence rate was slowly getting lower, but in 2019 it increased again to 130.6 cases (or 1407 infested people) found in 100 thousand people (Figure 3). Thus, despite the overall decrease of incidence rate in Tomsk oblast, the infestation remained high.

The total number of people infested with *Opisthorchis felineus* living in Tomsk oblast in 2019 was 1407. More than half of people infested were found to be children, numbering 561 cases, with an incidence rate of 246.6 cases per 100 thousand people.

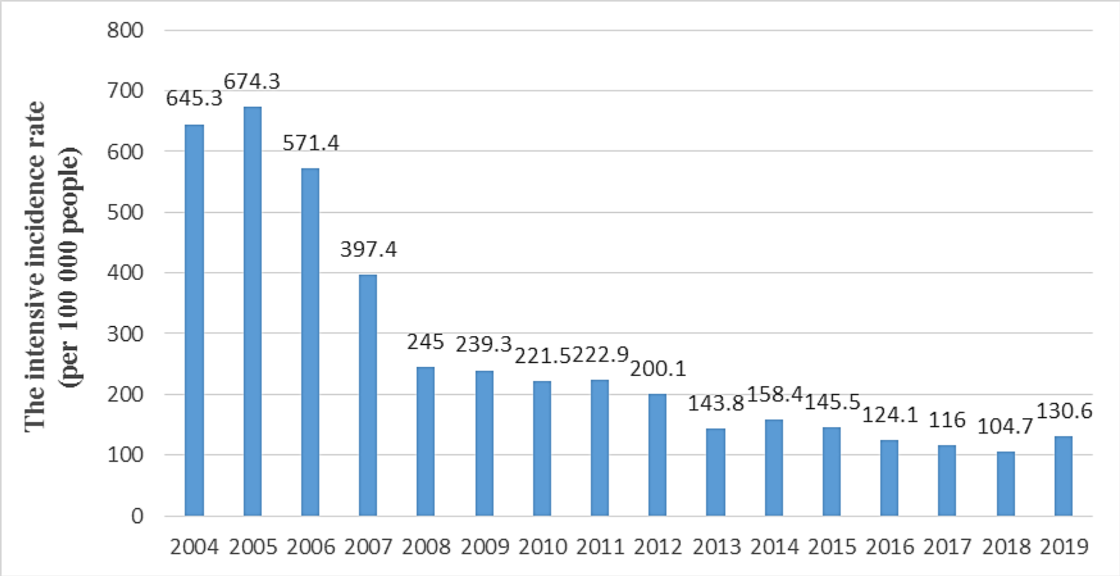

Figure 3 – Incidence rate of infested people with the disease Opisthorchiasis in Tomsk oblast from 2004 to 2019

Note: Based on the data about infested population in Tomsk oblast due to form №2 «Information about infective and parasitic disease approved by Federal service of state statistics' order » from 28.01.2014 № 52.

Infestation among children also was decreasing from 245 in 2014 to 193 cases per 100 thousand people in 2017. However, over the last 2 years, it rose to 247 cases per 100 thousand people, as shown in Figure 4.

According to the given data by the hygiene and epidemiology center of Tomsk oblast from 2017 until 2019, the city with the more intense incidence rate in Tomsk oblast was Kedrovyi city, with a mean of 375.8 cases per 100 thousand people; other cities, such as Tomsk, had a lower mean of 112.7 cases per 100 thousand people.

However, in 2019, the number of people infested with Opisthorchiasis significantly increased from 112.4 cases in 2017, to 133.5 cases in 2019 (based on Figure 5). Additionally, the incidence rate recorded in Strezhevoy city was 339 cases found per 100 thousand people.

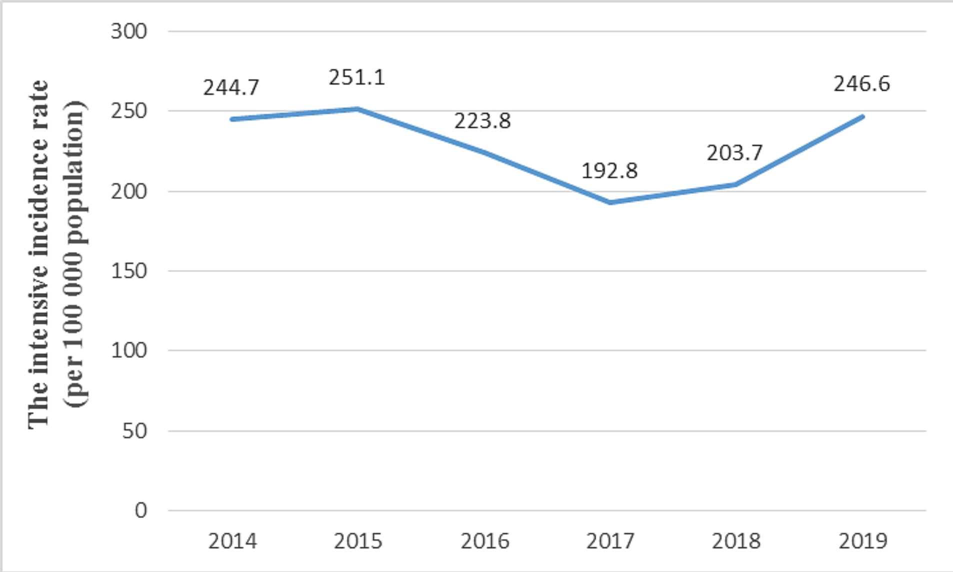

Figure 4 – Incidence rate of children infested with the disease Opisthorchiasis in Tomsk oblast from 2014 to 2019

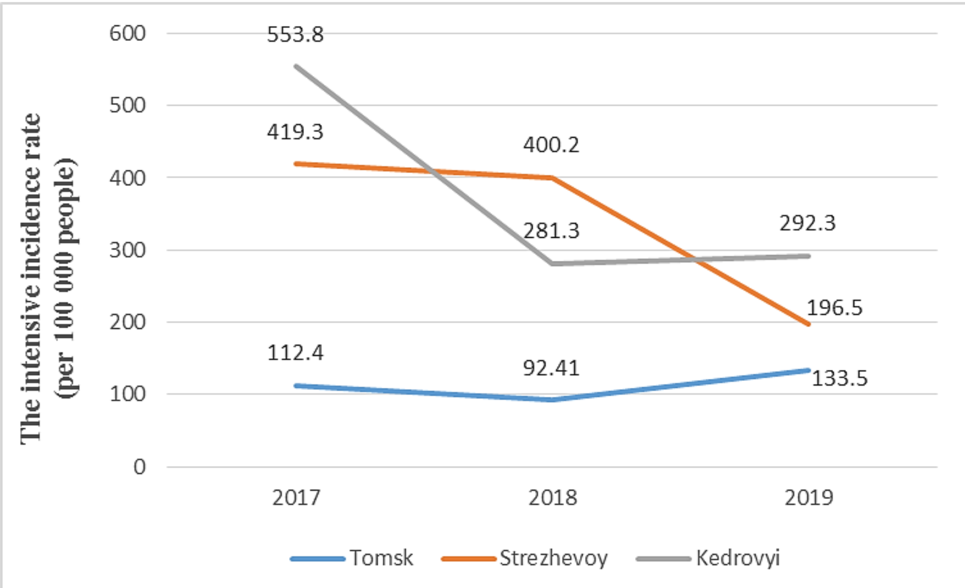

Figure 5 – The incidence rate of people infested with the disease Opisthorchiasis in cities of Tomsk oblast from 2017 to 2019

Due to the given data from the hygiene and epidemiology center in Tomsk oblast, from 2017 to 2019 the average incidence rate of people infested with the disease Opisthorchiasis was recorded from those who live in the following districts:

1. Aleksandrovskyi = 607
2. Kargasokskyi = 484

3. Tegul'detskyi = 368
4. Asinovskyi = 239
5. Kolpashevskyi = 121
6. Tomskyi = 114 (Figure 6)

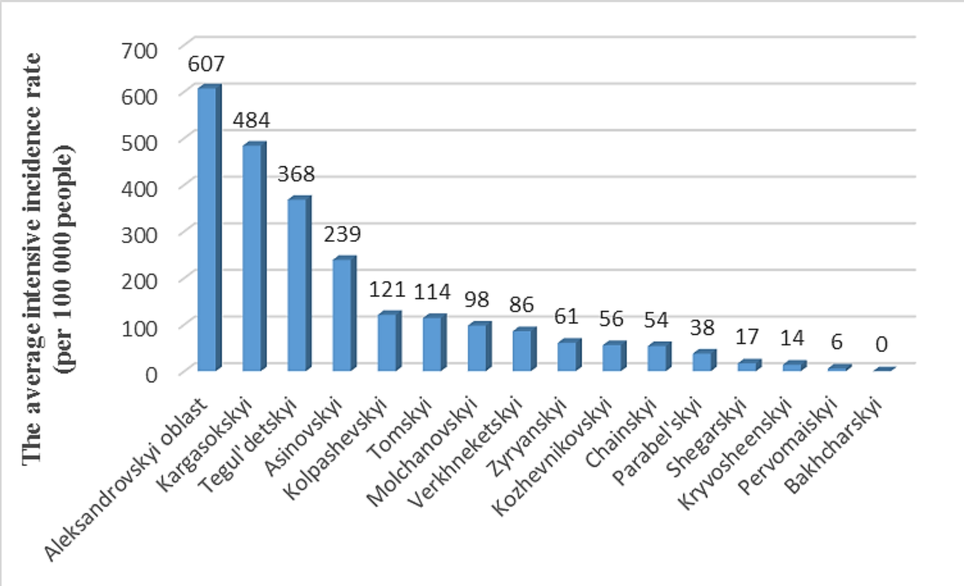

Figure 6 – The incidence rate of people infested with Opisthorchiasis in districts of Tomsk oblast from 2017 to 2019

The cause of these districts having a higher incidence rate has been attributed to poor natural–climatic and sanitary conditions: the presence of rivers with tributaries suitable for the inhabitation of the intermediate host, the river spill level, and the level of soil infested with metacercariae *Opisthorchis felineus*. In addition, certain eating habits, such as consumption of raw or unsalted fish, and poor sanitary conditions are common, not only among people living in cities, but also in the countryside or villages.

From 2007 until 2018 in Zyryanskyi district, the number of infested people was zero, but in 2019, it increased to 21. In some districts, such as Bakhcharskyi (2017–2019), Kryvosheenskyi (2017–2018), Pervomaiskyi (2017–2019), there were no infested people. In Pervomaiskyi district in 2018, the number of infested people was three, and in Kryvosheenskyi district in 2019, there were five infested people. The reasons for a low infestation level could be the absence or low number of infested carp fish in rivers and their tributaries, and low demographic density [Завойкин и др., 1979, цит. по Бочаровой и др., 2007].

It is important to mention that the official statistics about the disease Opisthorchiasis gives the approximate data because of applying different approach and methods to identify the incidence rate. Moreover, most infested people are not actually detected due to misdiagnosis, and thus they receive medical treatment for other diseases. Usually, statisticians pay attention to those whose diagnosis of Opisthorchiasis was detected for the first time or who get medical screening annually. People who have Opisthorchiasis can ignore their symptoms and not to go to hospitals at all. Therefore, there is a certain category of infested people who are not usually included in the database on epidemiology.

In conclusion, according to analyzed data on epidemiology in Tomsk Oblast, there was a significant decrease of infested people from 645.3 cases in 2004 to 104.7 cases distributed per 100 thousand people in 2018. However, in 2019, the incidence rate was slightly higher, and reached 130.6 cases per 100 thousand people. Therefore, despite having the significant decrease in incidence rate found in people living in Tomsk Oblast, the number of infested people infested by *Opisthorchis felineus* remained high.

2 Characterization of commercial species of carp fish in the Middle Ob basin

Compared with other sections of the river Ob, the Middle Ob basin has the greatest diversity of species [Romanov et al., 2017]. The Cyprinidae is the most diverse and largest family, both in terms of the number of freshwater fish (13 species of carp fish based on the latest publication of Romanov and others (2017)) and in catches obtained from the rivers. Carp fish widely inhabit rivers and lakes. Some fish such as ide, dace, bream, roach and crucian have had an enormous significance in the Siberian fishing industry. This family also has some representatives that are not indigenous species in Western Siberia, which were obtained from another place a long time ago. One of these is the bream. All of these commercial species mentioned before provide good fishery.

One of the species of carp fish that has a positive impact on the economy, contributing to livelihoods of the Western Siberian fishing industry is the ide *Leuciscus idus*. This species is a medium–sized fish, whose growth ranges from 300mm to 430mm, with a weight of around 680g [Wheeler, 1978]. The ide inhabits both rivers and lakes, and is quite well–distributed from the river Ob to the river Yana. The southern border of its distribution in West Siberia is the Black ocean basin, and the lower reaches of the Biys and Katuni (Altay). Ide also inhabit large lakes such as Ubinskoe, Chany, Sartlan, but they are absent in lake Teletskoye. This species is widely met in the middle and lower reaches of the river Ob. Despite the fact that this fish inhabits lakes, it is a river fish, and thus prefers areas with slower streams and clay types of soil [Попов, 2005].

One of the morphological features of this species is gill rakers that are short and meagre, and the number of them is from 9 to 13 on the first arch. Ide's teeth are conic and smooth (not serrated), and formed in two rows [Fishbase, 2008]. The fish has 47 vertebrae [Fishbase, 2008], and its body is moderately elongated and oval. The head is not large, and the forehead is convex. The anal fin is notched [Атлас пресноводных…, 2003], and its body colour is silvery yellow. Mature specimens are dark on the back and sides, above the lateral line; the lower parts of the sides are silvery. All fins are reddish in colour, especially the paired and anal fins. The iris of the eye is greenish–yellow [Попов, 2005].

In lakes, ide are usually found in schools, and they reach rivers to spawn on the vegetation. In the middle and upper streams of the river Ob, ide usually reach the floodplain in May when the water temperature reaches 6–7 degrees Celsius. The first fish that come to the floodplain are males [Гундризер, 1984].

The ide matures between the age of 3 and 5 years [Cala, 1971]. Its fecundity ranges from 17 to 300 thousand eggs. Ide come to the rivers in spring to spawn over vegetation [Fishbase, 2008], and after this process return to the coastal waters [Cala, 1970]. They eat actively after spawning (May and August inclusive). The ide feed on zooplankton (oar–legged and branched crayfish), and phytoplankton (diatoms, blue–green algae) in the first and early second years of life. From the second year of life, benthos – chironomide, daydream, and brooks are dominant in their nutrition, as well as shellfish and worms [Гундризер, 1984].

The next species that has commercial value in the Western fishing industry is dace. Its body is elongated. Dace is commonly distributed from the river Ob to the river Kolyma. In rivers such as the Ob and Irtysh, it is found from the upper reaches to the delta. This fish is a typical rheophilus, preferring clear rivers, with the rapid flow, and a sand, pebble, or rocky bottom [Попов, 2007]. Dace demand an oxygenated environment. If there is not enough oxygen, dace begin to experience respiratory depression, at 3–4mg of oxygen per a litre of water. In favorable conditions, according to the gas regime, it follows an active life in winter [Кириллов, 1972].

Sex maturity of dace occurs when they turn 3 or 4 years old [Кириллов, 1972]. 4–6–year–old dace are usually dominant in catches.

Dace *Leuciscus leuciscus* is one of the early spawning fish [Гундризер, 1984]. By the nature of the spawning substrate used in most reservoirs in Siberia, dace are a psammolithophytophilus, laying eggs on stony or sandy soil, or on vegetation, depending on the situation and the reservoir [Гундризер и др., 1959]. In terms of nutrition, dace eat both animal and plant food. According to Romanova G.P. (1949), in the floodplain river waters of the Middle Ob, dace eat actively from the end of May to June, and eat lightly in July–August. In late autumn and winter, dace hardly eat due to the low temperatures of waterways. The food spectrum narrows, and the intensity of digestion decreases in winter and autumn [Карасев, 1987].

In contrast to the native carp fish species mentioned earlier, the bream *Abramis brama* is one of the fish introduced to Western Siberia 100 years ago, and is well acclimatized to the Middle Ob reservoirs. Because of its introduction, the composition of carp fish has expanded [Интересова и др., 2017; Симакова и др., 2018; Симакова и др., 2019]. Because of gradual settlement, the Kuban bream inhabits many water bodies in Omsk, Tyumen, Novosibirsk, Kemerovo, Tomsk, Irkutsk, and Altai regions. From the reservoir of the Novosibirsk State District Power Station, the bream has settled upstream to the river Biya and upstream to lake Teletskoye. Down the river, the bream is caught throughout the Upper Ob, and a significant part of the Middle Ob.

Bream is a relatively large fish, with a tall body squeezed from the sides. Its head is small, and the back behind this rises sharply upwards, especially in adults. Its mouth is half-bottomed and small, but is able to move out strongly, forming a downward tube. Bream has 18–28 gill rakers at the first gill arch; swallow teeth are single–row consisted of 5–5, 6–5, rarely are they double–row: 2.5–5.2. There are 41–47 vertebrae in its spine [Гундризер и др., 1959]. During the breeding period, males appear in mating attire, in the form of epithelial tubercles located on the head, gill caps, and sides of trunk [Бабуева, 1969; Никольский, 1971; Купчинский, 1987].

In the upper and middle streams of the river Ob, the bream reaches puberty at 4–5 years old. Fertility ranges from 55 to 317000 eggs. In warm early spring, spawning begins when the water's temperature is 12–16^{o}C. In cold years, spawning takes place in June, and it lasts 20 days. Spawning takes place in lakes, reservoirs, and rivers. As a phytophilic fish, bream lays eggs on aquatic vegetation at depths from 0.5 to 1.5–2m. After spawning in lakes, the bream depart from the shore and are distributed throughout the water area [Гундризер и др., 1959].

Plankton organisms are dominant in bream's feeding at a young age. When it becomes older, it eats chironomide larvae (up to 48–90% of the weight of food lump), shellfish, worms, dragonfly larvae, brooks, and swampfish [Гундризер и др., 1959].

In Western Siberia, the Siberian roach *Rutilus rutilus* is more often called a Chebak [Попов, 2007]. The roach is a lake and river fish. It is found everywhere, from the southern part of the rivers such as the river Ob, to the river Black Irtysh and the Bukhtarma Reservoir. In Altai, the roach inhabits the lower reaches of Biya and Katun, while in Lake Teletskoye it is absent. Roach is in the lakes of the Altai steppe and the Barabinsk forest–steppe lakes. It also widely inhabits the upper reaches of the rivers such as the Ob and Irtysh, both in their tributaries and floodplain lakes. To the north, the roach population drops significantly. It can also be found in all weak–flowing and wastewater bodies with a favorable gas regime. The roach is particularly abundant in the ducts. It is found in smaller numbers in the main river channels.

In spring, after the ice melts, the roach gather in schools and migrate to spawning grounds. In lake water, the roach approach the shore or rush into rivers that flow into the lakes. In the rivers, the roach rapidly move to the floodplain, where spawning takes place. Usually, this process takes place hidden from human eyes, but sometimes it is possible to see thousands of migratory fish openly heading to spawning grounds [Гундризер, 1984].

The roach prefers to inhabit well-heated areas of water bodies with slow flow, often overgrown with vegetation. They rarely enter the central part of a deep lake, but prefer to spend the winter in pits. Roach are the most abundant in areas of rivers with a well-developed floodplain system [Попов, 2007].

The scales of roach are large. Its body is compressed from the sides, and the mouth is finite. All fins, except dorsal and caudal, have an orange–reddish tint. During spawning period, males and large females have epithelial tubercles ("Pearl rash") covering scales and gill caps [Атлас пресноводных…, 2003].

A roach becomes mature when it is 4 years old. During spawning, the fish are rough to the touch due to the numerous hillocks covering the scales and gill caps.

Absolute fertility of the roach varies from 8–83 thousand eggs. Young roach eat plankton organisms. Gradually mosquitoes and other insects, clams, and aquatic plants begin to be prevalent in their diet [Гундризер, 1984].

The next commercial species from Cyprinidae is the silver crucian carp *Carassius gibelio* (Bloch, 1782). This fish is an indigenous species from Central Europe to Siberia, while from Eastern Asia to European waters it is an introduced one. This species is not present in the northern Baltic basin, Iceland, Ireland, Scotland and the Mediterranean islands [Kottelat and Freyhof, 2007]. In Siberia, silver crucian carp is found from the river Ob to the Lena basin. The northern boundary of the range goes beyond the polar circle. One of the main features of this species is the fact that it has another Latin name, *Carassius auratus* (Linnaeus, 1758). Currently, *C.gibelio* is a selected neotype by Kalous L. and the ICZN confirmed the validity of its name [Dyldin, et al., 2016; Karlous, et al., 2012].

The crucian is a typical lake fish, but it can sometimes be found in floodplain rivers, where it goes from floodplain lakes during the flooding. It prefers deep and extensive water bodies [Петлина и др., 2004]. In winter, when oxygen is scarce, crucian fall into anabiosis, burying themselves in mud. However, under favorable conditions, crucian may be active in winter. This fish can live for more than 15 years in Siberian water bodies [Попов, 2005].

This fish has some morphological features. It has 31–51 gill rakers on the first gill arch, but sometimes it can only range from 44 to 47. The body is short and tall, with a dark green back, and silver sides and belly. The peritoneum can range from light grey to charcoal black in colour. In comparison with the golden crucian carp, its back fin is long with large scales [Попов, 2005].

The silver crucian eat plankton. The crucian reaches puberty at 3–4 years. The fertility of a crucian carp is quite good, especially in lakes of floodplain type or in vast lakes – the quantity of eggs is from 20–200 thousand [Гундризер, 1984].

A feature of silver crucian in the waters of Western Siberia is that in schools almost no males are found. Golden crucian have a ratio of males to females ranging from 1:1. In Western Siberia, for every 100 silver carp females there is 1 male, and in some reservoirs there are only 1–2 males for 1000 females.

Fertilization of silver crucian is achieved through the sperm of other fish species, such as golden crucian carp, minnow, carp [Гундризер и др., 1984]. In Siberia, crucian spawning takes place from the end of May to August, with a water temperature of at least 15–16ºC. Spawning occurs at a mass gathering of crucians. Caviar is sticky and deposited on the aquatic vegetation of a small body of water. During 5 days, the caviar develops at a temperature of 18–20ºC [Гундризер, 1984].

Thus, today, ide, dace, bream, roach and crucian are commercial species inhabiting the river and lake water bodies of the Middle Ob. According to literature data, the ide reaches sexual maturity at 5–6 years. Dace, roach, crucian and bream reach sexual maturity at 4–5 years. Ide prefer rivers with fast currents, while roach prefer the rivers with slow currents. Dace are more demanding of oxygen than roach. They all feed on chironomide larvae and planktonic organisms. Knowing the basic morphological and physiological features of commercial carp fish species not only allows the significant strengthening of the development of Siberian fishery, but also to conduct various studies on their infestation.

3 Studying Commercial species of Carp Fish infested with metacercariae *Opisthorchis felineus* in Tomsk Oblast

The secondary intermediate host, coming after the molluscs (first intermediate host), participating in life cycle of *Opisthorchis felineus* is carp fish. They play an enormous role as a secondary intermediate host, giving the parasite a chance to come to the next stage of development in its life cycle. Thus far, it has been established that 13 species of carp fish inhabit the Ob–Irtysh basin, five of which are commercially fished [Romanov et al., 2017].

Investigation carried out in oblasts such as Tymenskoe, Kemerovskoy, and in some Western oblasts of Kazakhstan have identified the high rate of infestation in species such as ide and dace, and lower infestation rate found in species such as roach. Similar investigation was done in Tomsk Oblast.

In 1936, the first investigation of infested carp fish obtained from the river Basandayka were conducted by S. D. Titova (1946). She observed 166 specimens by applying the full helminthological autopsy. No parasites were found in muscles of the observed specimens. 43 specimens of dace were obtained from that river in 1953, five (11.6%) of which were infested with the parasite *Opisthorchis felineus*. The intensity of the infestation recorded in infested dace increased from two metacercariae to nineteen metacercariae [Мясоедов, 1960].

From 1989 until 1991, Bocharova and co-authors were trying to detect infested carp fish obtained from the river Ushaika. 150 specimens of 11 types of carp fish were observed by applying full helminthological autopsy.

From 1997 until 1998, the investigation was done in rivers, such as Basandayka and Tugoyakovka. In this research, 33 specimens were studied, and two of them were subjects of our research: roach and dace. The roach had three metacercariae, while in the dace there were twenty. No parasites that could be considered pathogenic for people were detected in the muscles of the observed specimens.

From 1999 until 2003, 294 specimens of dace obtained from the river Ushaika were observed. In 2002, metacercariae of a cat liver fluke were found in the muscles of dace obtained from the river Ushaika, with a prevalence of 14.3%. The highest intensity of infestation was 10 metacercariae detected in one fish. In 2003, the prevalence rose to 50%.

In 1997, T.A. Bocharova and others first studied carp fish that were obtained from the river Tugoyakovka and infested with metacercariae. Fourteen dace specimens were obtained from around 100km of the river Tom. For the first time, it was recorded as a hotbed of dace infested with Opisthorchiasis. At that time, the prevalence of infestation reached 35.5%.

Investigation carried out in those rivers from 1999 until 2000 demonstrated prevalence increasing in infested dace (Table 1). In 2002, it reached 85.7% and then in 2003, it dropped down to 67.1%. This drop could be the consequence of changing water level.

The average intensity remained the same, with a range of 7.4 to 12 metacercariae found in a small section of the back muscle of the lower dorsal fin [Bocharova et al., 2007]. It was seen that the infestation rate of carp fish obtained from different water bodies was different, and it could be higher in the main river, such as the river Ob, than in its tributaries. Infestation was observed to be higher in rivers from south to north, but in tributaries increased infestation was seen from upper to lower reaches.

Infestation was higher in floodplain lakes than in mainland lakes. The highest rate of infested fish with parasite *Opisthorchis felineus* was recorded in the river Ob (In Kargasok village, ide – 94.5%; dace – 94.7%; roach – 8.5%) as Table 2 shows.

Dace had lower infestation rate in tributaries such as Ket – 58%, Chaya – 20%, Tuym – 5.8%, Parabel – 52.8%, Chulym – 39.8% [Бочарова и др., 2007].

Much attention was dedicated to studying one of the larger tributaries of the river Ob–Vasyugan. The Vasyugan basin includes rivers and lakes of the Taiga river system, and occupies 62000km^2. Investigation conducted from 1964 until 1974 showed the presence of synanthropic and natural outbreaks of Opisthorchiasis in that area.

Table 1 – The dynamics of dace infested with *Opisthorchis felineus* in small tributaries of the river Tom [Бочарова и др., 2007]

Tribularies	1997	1999	2000	2002		2003		2004	
	P,%	P,%	P,%	P,%	I	P,%	I	P,%	I
River Ushaika	–	–	–	14.3	1–10/4	50	1–24/6	–	–
River Basandayka	19.2	20.2	43.6	–	–	–	–	97.1	1–69/6.3
River Tugoyakovka	35.5	44.4	45.6	85.7	1–36/7.9	67.1	1–104/12.0	–	–
Note: P–prevalence,% ; I–intensity(the min, max number and the average number of metacercariae (larvae) found in fish)									

Table 2 – Dynamics of infested carp fish with parasite *Opisthorchis felineus* found in rivers of Tomsk oblast [Завойкин и др., 1989; Бочарова, 1998; Бочарова и др., 1999, 2002–2005]

Species	Middle Ob			river Chulym		river Vasuygan		river Ket
	2000	2002–2003	2004–2005	1989	1999	1974	1998	2004
Roach	15	No data	8.5	1.3–2.5	–	7.7- 18.8	5–26.4	2
Ide	94.5	–	–	38.1–60	–	35-70	25–66	–
Dace	98.9	75	94.7	28.8–68.7	39.8	22.7–45	13.4–50	58

Around 2000 specimens of carp fish were observed from three water bodies – the river Vasuygan, the floodplain and mainland lakes. Here the infestation rate in ide ranged from 35 to 70%; dace – from 22.7 to 45%; roach – from 7.7% to 18.8%. In some floodplain lakes of the lower reaches of the river Vasyugan, located by fully populated villages such as Staroyugino village, the infestation rate found in dace reached 100% [Бочарова и др., 2007].

From 2001 until 2005, Bocharova and others examined 1700 specimens of 11 types of carp fish obtained from areas such as Tomsk city, Kaftanchikovo village, and Orlovka village. Ide and dace were much more infested with metacercariae of *Opisthorchis felineus*. The general percentage of infested carp fish from the lower streams of river Tom was 70.3%, and it fluctuated based on the place from which the fish was caught – it was 73.7% in Tomsk, 87.1% in Kaftanchikovo village, and 50% in Orlovka village (Table 3) [Бочарова и др., 2007].

The prevalence of infested dace was 84.5% in Tomsk, 88.7% in Kaftanchikovo village, and 89.4% in Orlovka village. This indicates to the fact that the prevalence of infested fish grew from the beginning of the river to the end of it. The infestation found in dace was less intense than the one found in ide.

In 2003, Bocharova and others found out the relationship between the number of parasite *Opisthorchis felineus* found in dace and the fish age. To come to such a conclusion, they observed 524 specimens of the following 3 age groups: juveniles, containing 291 specimens; 3–year–old fish, containing 147 specimens; 4–year–old fish, containing 86 specimen. All of them were taken from the river Tom near Kaftanchikovo village. The researchers concluded that the infestation found in dace was getting higher in older specimens, as it had a significant increase from 19.9% found in juveniles, to 98.8% in 4–year–old specimens [Бочарова и др., 2007].

Long–term research dedicated to detecting the inf ested dace were conducted with specimens from the river Tom, which showed a high prevalence of this species. According to Bocharova and co–authors' research (1983) conducted from 1977 until 1978, the prevalence of infestation in dace was 66.4%. From 1997 until 2004, there was a significant increase in prevalence, up to 95.7%.

From 2004 until 2005, the research in which 249 specimens of dace were caught from the river Tom (in the Kaftanchikovo village) showed the slight decrease in prevalence – 92.5%, which could be associated with water level.

Table 3 – The infestation rate of some carp fish with metacercariae of cat fluke from the lower reaches of river Tom (2001–2005) [Бочарова и др., 2007]

Species	river Tom					
	In the area of Tomsk city		In the area of Kaftanchikovo village		In the area of Orlovka village	
	P.,%	I.(min–max/average)	P.,%	I.(min–max/average)	P.,%	I.(min–max/average)
Roach	—	—	3.6	1	1.8	3
Dace	84.5	1–2/10.4	88.7	1–53/5.7	89.4	1–102/14
Ide	—	—	100	8–46/24	90.9	6–141/30.2
The number of observed fish	99		929		244	
The number of infested fish	73		810		122	
The general percentage of infestation, %	73.7 %		87.1%		50.0%	
Note: P – prevalence,%; I – intensity of infestation						

According to literature data, the infestation rate of roach from the lower stream of river Tom decreased from 2000 until 2005. The intensity of infestation of roach in those years fell from 15.0% to 8.5%. No infested bream and crucian were found [Бочарова и др., 2007].

Many scientists consider that crucian do not play the role of a secondary host participating in life cycle of trematode *Opisthorchis felineus*. Research conducted by Pelgunov in 2010 supports this claim. 170 specimens of crucian were considered in this study (both gold and silver), all caught from the Tobol'sk biological station. Pel'gunov did not find the specimens infested with the parasite *Opisthorchis felineus*, despite the fact that the crucian was caught in the areas where the infestation rate of other species of carp fish, such as ide and dace, was high. The same result of no infested crucian was obtained from an investigation carried out in Novosibirsk Reservoir [Бонина и др., 2011]. Both sets of research provide good evidence of crucian's incapability to be infested with the parasite *Opisthorchis felineus*. Therefore, it is clear that including crucian in the list of secondary intermediate hosts participating in the parasite's life cycle could be wrong.

In the floodplain of the river Ob, located near Novosibirsk city, there were no infested bream specimens, while in other research (2009), infestation was seen to have prevalence, with a range from 3% to 15% [Бонина и др., 2011; Бонина, 2017]. Parasitological studies in the Middle Ob Basin did not reveal infested bream. All investigated bream were free from infestation [Соусь, Ростовцев, 2006; Бочарова, 2007].

Thus, the crucial role of dace in maintaining the Opisthorchiasis hotbed from the lower streams of the river Tom is connected with its high infestation rate and high population number. Ide also plays an important role in the development of the parasite. As the result of this, they are one of the main carriers of metacercariae of *Opisthorchis felineus*. Roach has less prevalence of infestation, and therefore contributes less to supporting the lifecycle of parasite *O. felineus* in Siberian waterways [Бочарова и др., 2007]. Bream, as the previous research discussed show, had high prevalence of infestation in their natural habitat, where they originally come from. In the areas where the bream is not an indigenous species, it usually has a lower prevalence. Despite this, bream could also be participating in the spread of parasite *Opisthorchis felineus* and maintaining its life cycle [Simakova et al., 2019]. Up to this point, no researcher has identified any infested bream in the Middle Ob basin.

The result of analyzed data allows us to draw a conclusion concerning the unfavorable epizootic state of the surveyed water bodies, with respect to infestation by trematode *Opisthorchis felineus*.

4 Methodology

4.1 Physico–geographical characteristics of the research area

Our present research was conducted in the area of the Tomsk oblast. The Tomsk region is located on the territory of the Ob–Irtysh basin, which is known for being the world's largest hotbed of the disease Opisthorchiasis.

The Tomsk Oblast has 18100 rivers, streams, and other waterbodies, with a total length of about 95000km. The river Ob is 1170km long within the Tomsk region [Савичев, 2010], and it is situated in the middle of the Eurasian continent. The river Ob is confined to the south – eastern part of the West Siberian Plain, which is the largest in the world. The length of the region from north to south is about 600km; from west to east, around 780km. The region borders the Tyumen Oblast to the north, the Omsk Oblast to the west, the Novosibirsk and Kemerovo Oblasts to the south, and the Krasnoyarsk territory to the east.

The river Ob is the longest river in Russia. This river spans 2929000 km^2 [Romanov et al., 2017]. It is between 30km and 50km wide, its floodplain is at least 30km wide, and is covered with numerous channels and lakes. In its stream, the river Ob is divided into three sections, which differ in the nature of the river networks, feeding conditions, and the formation of the water regime: the upper section – to the inflow of river Tom, the middle section – to the inflow of river Irtysh, the lower section – to the Ob Bay. Within the Tomsk Oblast, there is the lower section of the Upper Ob, and the upper part of the Middle Ob, with a total length of 1169km. [Иоганзен, 1971]. After merging with river Tom, the river Ob increases its power, and to the inflow of the river Irtysh, it becomes more aqueous. In this part, the river has a wide floodplain, with a large number of rivers and lakes. The floodplain here is important for fish reproduction, their growth, and fish conservation in winter, especially in connection with the freezing of the water bodies [Вовк, 1951; Romanov et al., 2017].

The main right tributaries of the Middle Ob basin are the river Tom (839km), the river Chulym (1733km), the river Ket (1360km), the river Tym (1000km), and the river Wah (1124km). The main left tributary is the river Vasyugan (1120km).

The main sources of feeding for those rivers are winter precipitation, which forms 55–82% of the annual flow; groundwater, which accounts for 10–40%; and rainwater, which comprises 3–11% of annual flow [Ресурсы поверхностных вод….., 1972]. In terms of hydrological regime, the rivers are of the West Siberian type. The rivers have long spring summer floods, with duration of 1–2 months. The river Ob has a predominantly snow–fed diet. During spring and summer floods, the river Ob brings the bulk of its annual flow. The floods begin in the middle reaches in the second half of April; in the lower reaches, it lasts from the end of April and early May, and continues until autumn.

In the middle and lower reaches of the river Ob, the floods continue through to fall with lowered rain leashes, until they reach freezing point. Based on the long flood, the river flows widely along the valley, and connects numerous shallow floodplains. Here, spawning and feeding of carp fish takes place during the warm period. Such areas of the valley are associated with colonies of molluscs. In the same reservoirs, there are all the necessary conditions for the development of larval stages of helminth, the formation of cercariae that could infest second intermediate hosts such as carp fish, and the conservation and accumulation of metacercariae in fish populations [Солдатов, 2011].

Fish death phenomena is ecologically significant for the water bodies of Western Siberia, covering almost all of the entire lake and river networks in the middle and lower reaches of the river Ob. Fish die because of the accumulation of a huge amount of organic substances in the surrounding lake–marsh systems, which are gone out into the main watercourses. As a result, during the freezing period, fish suffer from a lack of oxygen, which can lead to mass death [Мосевич, 1947].

That is why, because of the appearance of ice and the decrease of the amount of oxygen in the water, fish usually leave shallow waters and move to places of wintering, contributing to the spread of parasites to large areas.

According to the degree of development of fish death phenomena, the river Ob divides into 3 sections: non–fish death – above Kolpashevo; Transitional section with incomplete and not annual fish death – from Kolpashevo to the mouth of Tyma; fish death – below Tyma.

According to Johanzen (1971), the upper section of the Middle Ob basin, with a length of 270km (from the confluence with the river Tom to the river Kolpashevo), reaches to the lake upper river Ob non–overseas region. The lower section (to the mouth of river Irtysh), with a length of 1226km, extends to the Middle Ob. The fish habitation connects with a floodplain, defining the basic fish productivity of the basin [Дрягин, 1948, Москаленко, 1956, Никонов, 1977, Петкевич, 1965, 1971].

The height and duration of the flooding have a huge impact on feeding and breeding, as well as on fish numbers and catches. Fattening of some species of fish usually occurs in the floodplains. In this kind of area, phytophilic fish usually breed. Floodplains play an important role in the development and survival of juvenile fish. Moreover, the water level in the floodplain plays an enormous role for fish in terms of reproduction, fattening, and growth [Замятин 1977; Рыбохозяйственное использование…,1983].

According to literature, the river Tom is one of the largest right tributaries of the river Ob. It crosses 3 geologic and geographical regions in its length: Kuznetskiy Alatau, Kuznetskaya hollow, and Kolyvan – Tomskaya fold zone. Tom basin is located in the south of Western Siberia, and has a catchment area of 62000km^2. Most of its area is located in the Kemerovo region (49780km^2 or 80.3%), the smaller area of that basin is in the Tomsk region (6900km^2 – 11.1%) and in the Republic of Khakassia (3600km^2 – 5.8%). Some parts of the catchment are located within the Novosibirsk Region (1240km^2 – 2.0%), the Altai Territory (250km^2 – 0.4%), and the Republic of Altai (230km^2 – 0.4%) [Шварцев и др., 2006].

The river Tom begins on the western marshy slope of the Abakan Range, between the northern spurs of the Karlygan Range and Vershina of the Tom mountain. The river is 827km long, and its area is 18000 hectares. The width of the floodplain is up to 3km, the channel width varies from 250–650m, and the elevation difference from the source to the mouth is 1185m.

The river Tom includes mountain-taiga and forest-steppe sections. Its peculiarity is the oligo–mesotrophicity of river waters [Зарубина и др., 2001]. The river Tom is characterized by a mountainous river regime. Fish death phenomena is not characteristic of the river Tom, which is important for wintering of fish species coming from the river Ob. In the river Tom, pebbles and coarse sand are the dominant soil type.

The largest tributaries of the lower river Tom are the river Tugoyakovka, the river Basandaika, the river Ushaika, and the river Kirgizka on the right bank; the river Bolshaya Chernaya, the river Chernaya, and the river Kislovka on the left bank.

The river Basandaika is in the southeast of Tomsk Oblast, and is the right tributary of the river Tom. The whole river basin is located in the Tomsk district. The river flows into the river Tom 5km above the city of Tomsk, in the area of the Anikino village, in a valley 1km wide. The river in its upper reaches has 14 rills and numerous small channels. The main tributaries are the river Lomovaya, the river Berezovaya, and the river Nefedovka.

In summing up the above–discussed study and results obtained, it says that the Tomsk region is full of rivers with their tributaries, located in the area of the largest hotbed of Opisthorchiasis, which is Ob–Irtysh basin. Understanding the physico–geographic location of the researched area could be helpful in comprehending how the discussed factors may affect the infestation rate, as well as how relevant studying the disease Opisthorchiasis could be. The acquired knowledge can then be applied in making an appreciably deductible comparison between different water bodies, in accordance with the infestation level of fish. The study, therefore, helps to control the mechanism applied in the disease prevention modalities.

4.2 Fish sampling

The material for the master's thesis was some commercial species of carp fish obtained from 2018 until 2019 from three water bodies. The first of which was the river Ob, in the area of Melnikovo village (56º32'50.92" N 84º09'36.83" E). The second water body was river Tom in the area of Tomsk (56º46'37.38" N 84º93'15.11" E), and the third one was the river Basandayka, in the area of Aniknino village (56 º24'41 .00" N 84º58'50.70" E) (Figure 7).

Figure 7 – Water bodies where research material was taken from 2017 until 2019: river Ob and river Tom and river Basandayka

For this research, the data kindly provided by the Department of Zoology of invertebrates from the collection of the earlier years of research conducted in 2017 was used.

From 2017 until 2019, we investigated and analyzed 768 specimens of carp fish belonging to five species: ide, dace, bream, roach and crucian, as Tables 4; 5; 6 illustrate. From that total number of fish, there were 243 roach specimens *Rutilus rutilus* L. (Linnaeus, 1758), 231 dace specimens *Leuciscus leuciscus* L. (Linnaeus, 1758), 74 ide specimens *Leuciscus idus* (Linnaeus, 1758), 146 bream specimens *Abramis brama* (Linnaeus, 1758), 74 silver crucian specimens *Carassius gibelio* (Bloch, 1782).

Table 4 – The quantity of observed species of carp fish in 2017

2017									
Species	January	February	March	May	June	July	October	November	December
Roach	22	—	—	13	10	—	—	—	—
Dace	—	—	25	—	—	—	41	21	22
Ide	—	—	—	4	—	—	18	—	—
Bream	2	—	—	—	—	5	—	—	—
Crucian	—	—	—	—	—	—	—	—	—

Table 5 – The quantity of observed species of carp fish in 2018

2018					
Species	May	June	July	October	November
Roach	—	8	78	2	—
Dace	—	—	2	31	22
Ide	3	6	—	14	—
Bream	—	20	78	17	—
Crucian	—	—	—	—	72

Table 6 – The quantity of observed species of carp fish in 2019

2019							
Species	February	April	May	June	July	September	October
Roach	30	—	18	46	16	—	—
Dace	—	20	—	17	—	30	—
Ide	3	—	7	7	6	—	6
Bream	4	—	2	8	5	—	5
Crucian	—	—	—	2	—	—	—

All of the specimens were caught using a set of nets with a length of 75m, and cells of different sizes: 20, 30, 40, 50, 60mm. The time spent setting up nets was up to 12 hours.

4.3 Data processing and its analysis

In addition to that, our material was observed by performing a *biological analysis* proposed by I.F. Pravdin in 1966. Under laboratory conditions, the following parameters were enforced: maximum total length (MTL) – from the top of the "snout" to the end of the longest ray of the caudal fin, maximum standard length (MSL) – from the top of the "snout" to the beginning of the caudal fin, and Q – body weight.

The age and gender of fish were both determined [Романов и др., 2012]. To determine age, the number of sharply pronounced wide circles on a rather thin plate was taken into account–scales. Besides rather visible circles, on the scales there were lines resembling rings. Scales were used for weighing fish. A line or measuring board was used to determine the fish length. All data was recorded in a special journal with the date and place of fishing.

Then, the *parasitological analysis* began. To determine the infestation of the fish, based on the number of metacercariae (larvae) found in one particular fish, a full parasitological autopsy was performed, in which the fish muscles were observed completely. This parasitological method is also known as *the compressor method*. With the help of sharp tweezers, scales were removed prior to the autopsy. Muscles were also removed from the body. After this, muscles with a thickness of 2–3mm were viewed with the help of microscope "MBS–9" [Беэр и др., 1987]. Two compression glasses of different sizes were used to observe the muscles: a lower one, measuring approximately 10×15cm, and a standard upper slide. A prepared thin piece of the muscles was put at the top of the lower glass. Small pieces of muscle were cut off by the glass corner and put them tightly between the glasses. When a piece of muscle was dry, it was moistened with water through the help of a pipette [Беэр, 2005]. If helminth eggs were not in this area, a similar thin piece of muscle was taken from another part of the body [Бауер и др., 1981]. Identification of the trematode was done using scholarship, which is named as «Identification of Parasites found in Freshwater Fish» (1987).

Mathematical data processing was carried out. The following measures were used to identify quantitative and qualitative indicators of larvae *Opisthorchis felineus* infestation and its spreading [Беклемишев, 1970]:

Prevalance (P) – number of infested individuals from the total number of investigated specimens. P is expressed by the following formula:

$$P = \frac{n}{N} 100\% ,$$

Where *n* – the number of infested specimens, *N* – the total number of specimens.

The intensity of infection (II) is the average number of parasites found in one infested specimen and this measure is determined by the following formula:

$$II = \frac{m}{n} ,$$

Where *m* – total number of parasites detected in infested specimens.

Abundance index (AI) is the average number of parasites found in total number of specimens, including not infested individuals:

$$AI = \frac{\sum m}{N} ,$$

where N – total number of specimens including infested and non–infested ones.

Data was included in the "Electronic Research Map" and statistically processed using the program Excel. Besides Excel, we used some statistical tests, of which one was a Spearman rank correlation test for identifying the relationship between the host's length, weight, age, and its parasite intensity. This test is recognized as a non-parametric test [Kabacoff, 2011] that is more applicable when data is not normally distributed (Shapiro-Wilk test, $p < 0.05$), as shown in our all cases. In the case of our data sample being small, for getting an accurate result, we applied another non—;;parametric Kendal correlation statistical test [Kabacoff, 2011]. We calculated all of these statistical tests in R software.

We have ordered species of carp fish in the section of our results in accordance with their infestation level.

5 The commercial value of carp fish in the Ob–Irtysh basin and their infestation with parasite *Opisthorchis felineus*

According to N.N. Plotnikov (1953), the probability of when humans could be influenced by having disease such as Opisthorchiasis is defined by how well commercial fishery in the particular area is developed, and also eating habits, for example whether they eat raw fish or feed this fish to pets, such as dogs and other mammals, giving them fish that is infested with larvae. Moreover, it depends on the prevalence and intensity of infestation of the fish. Infestation of humans and carnivores occurs as the result of eating raw, not salty or undercooked fish, with parasites.

The analysis of catches of some species of carp fish was being done for the last 7 years to help identify the commercial value of theirs. It could be helpful to understand what species should be deeply learnt on presence of parasites. In order to identify their infestation, we found some quantitative measures such as prevalence and intensity of infestation and abundance index. The relationship between parasite intensity and fish characteristics was found by the help of performing the statistical tests.

5.1 Commercial value of carp fish in the Ob–Irtysh basin

Fishing is the important industry in Tomsk oblast. Fish is a significant resource of economical capability for the West Siberian region. In the pre-revolutionary Russia, commercial catches in the river Ob and river Irtysh played an enormous role in providing the population with fishes. In the Soviet time, the West Siberian region contributed to at least 25% of all fishes that were being caught from the rivers and lakes, and 75% of catches was taken from Siberia.

The great capability of bio resources from Siberian water bodies is not overlooked yet. Fish commercial areas occupy 500 thousand hectares on different water bodies. The most productive water bodies of floodplains (25% of the water area, catch 50kg hectares), river bodies (45% of the water area) and taiga lakes (30%)

produce significantly less (20kg and 10kg hectares, respectively). The Ob–Irtysh basin accumulates a huge amount of biological resources, as well as providing many fishes [Экология рыб Обь – Иртышского бассейна, 2006].

The largest family is that of the carp fish, Cyprinidae, which currently includes 9 indigenous and 4 introduced species (carp, bream, bleak and verkhovka). Both commercial and amateur fishery of this family is well developed [Санкин, 2008].Today, there are 13 species of carp fish [Romanov et al., 2017]. 5 of 13 species of carp fish have commercial value. There are ide, dace, bream, roach and crucian, while others of the 13 species are objects of amateur catches. In most of Siberian water bodies, the fishing stocks of dace are currently good [Слепцов, 2002]. In the upper streams of the river Ob, dace is the object of amateur fishery, but in the middle and lower reaches of river Ob, it has the commercial value.

Based on the long–term data on fishery given by the Upper Ob Territory Management of Federal Agency (enquiry from 17.04.2019 №2287) from 2012 until 2018, in the area of Tomsk oblast there was more than 200 tons of ide, bream and roach being caught from the river Ob. In lakes, there were more than 100 tons of crucian and around 55 tons of roach. In the rivers, the prevailing species in catches were dace and bream. In the river Chulym, bream were prevalent, while others were less so, as Figure 8 clearly shows.

From 2012 to 2014 in the river Ob, the catches of ide slightly shot up from 146.5 tons up to 236.3 tons. However, next year, it reduced to 224.2 tons of ide in 2015. During the last 3 years, it has been going up to 419 tons (Figure 9). The average ide catch over the last 7 years was 275.1 tons.

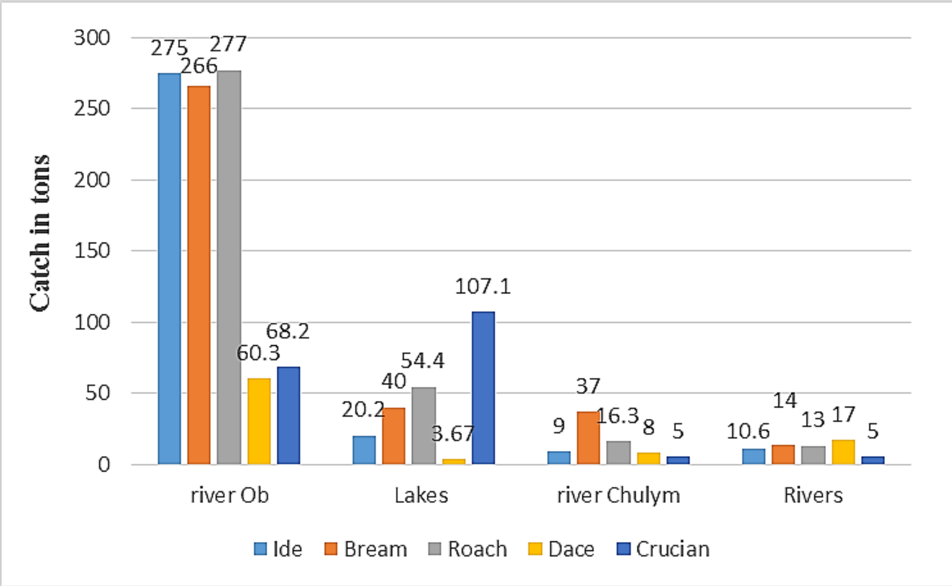

Figure 8 – The structure of commercial catches in the area of Tomsk oblast from 2012 until 2018 (in tons)

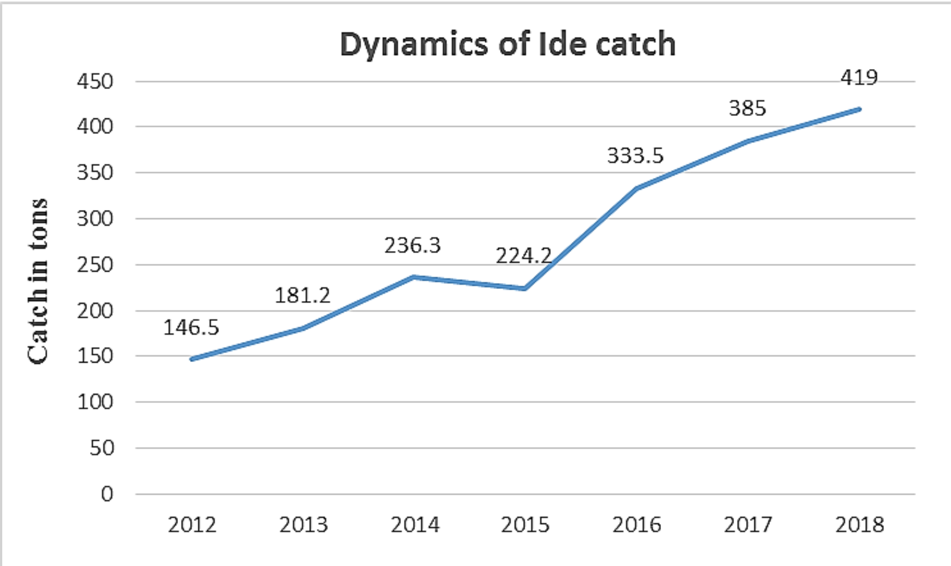

Figure 9 – The catch dynamics of ide obtained from the river Ob

As annual catch dynamics of dace show that from 2012 to 2018, the number of it ranged from 44 to 81 tons. From 2012 until 2014, the catch of dace from river Ob ranged from 44 to 57 tons. Then, it slightly plunged to 52.5 tons in 2015 and then, there was a sharp increase to 75 tons in 2016. Over the last 2 years from 2017 to 2018, the number of obtained ide ranged from 68 to 81 tons, as Figure 10 illustrates. The average dace catch over the last 7 years was 60.3 tons.

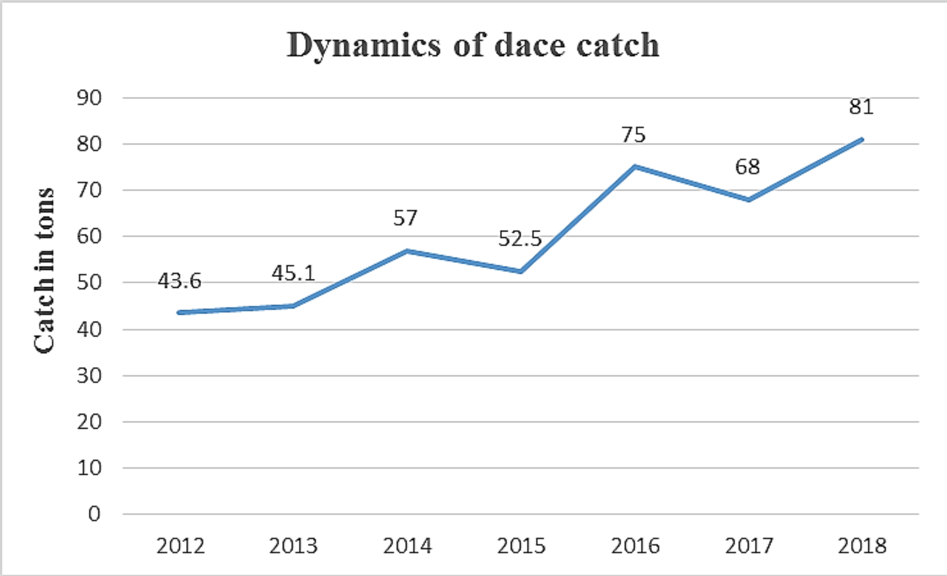

Figure 10 – The catch dynamics of dace obtained from the river Ob

Due to the data from 2012 to 2018, the catches of bream were noticeably rising up from 129 to 385.2 tons, as Figure 11 shows. The average bream catch over the last 7 years was 266 tons.

From 2012 to 2014, the number of roach being caught from the river Ob ranged, and it raised from 152.4 up to 271.2 tons. Then, it reduced to 258 tons in 2015 (Figure 12). Next year it increased to 380.1, which had a slight decrease to 341.4 tons in 2018. The average roach catch over the last 7 years was 277 tons.

In the area of Tomsk oblast in the river Ob in 2012, crucian were not being caught. Then, from 2013 to 2018, the number of obtained crucian ranged. The number of crucian climbed from 57 in 2013 to 124 tons in 2016. Then it fell down to 103 tons of crucian in 2018 as Figure 13 shows. The average crucian catch over the last 6 years was 68.2 tons.

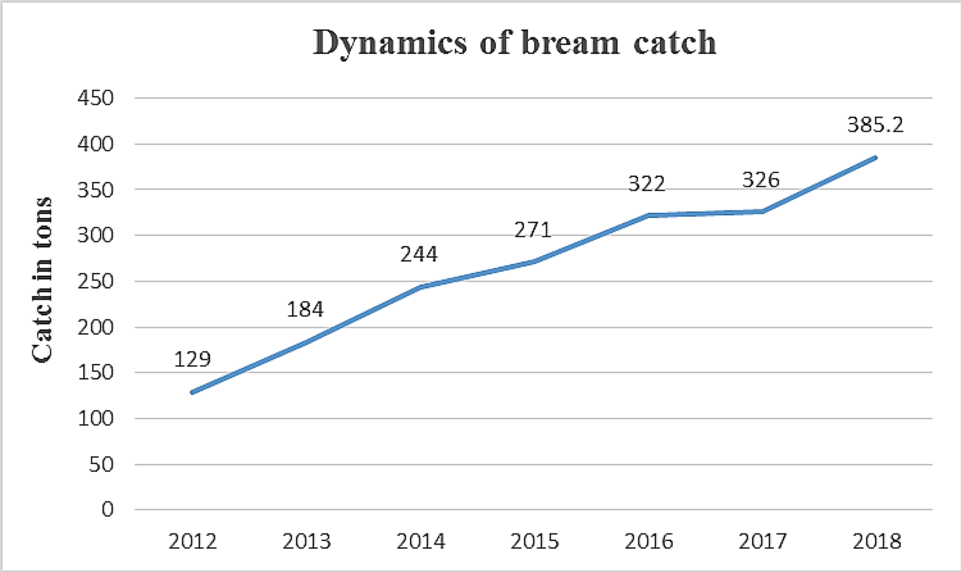

Figure 11 – The catch dynamics of bream obtained from the river Ob

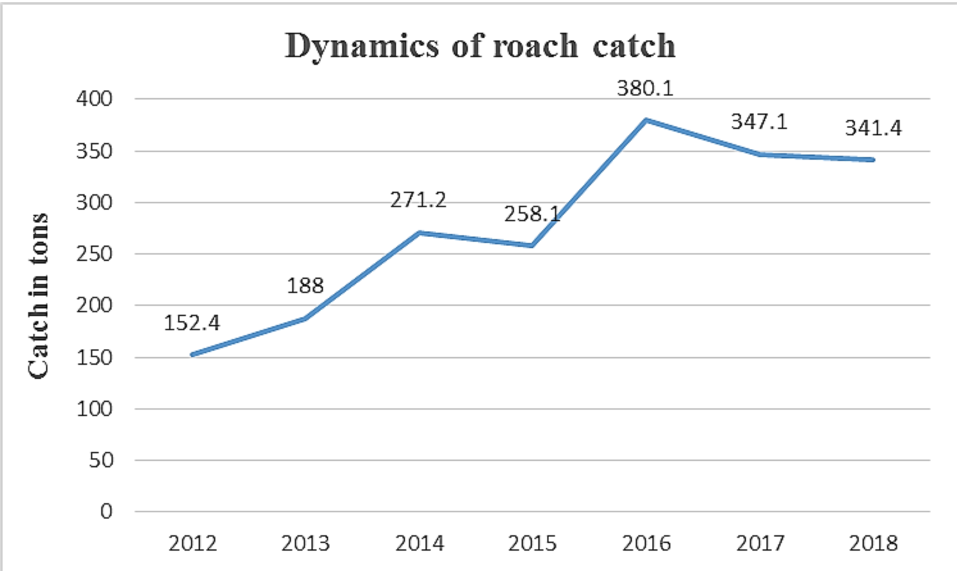

Figure 12 – The catch dynamics of roach obtained from the river Ob

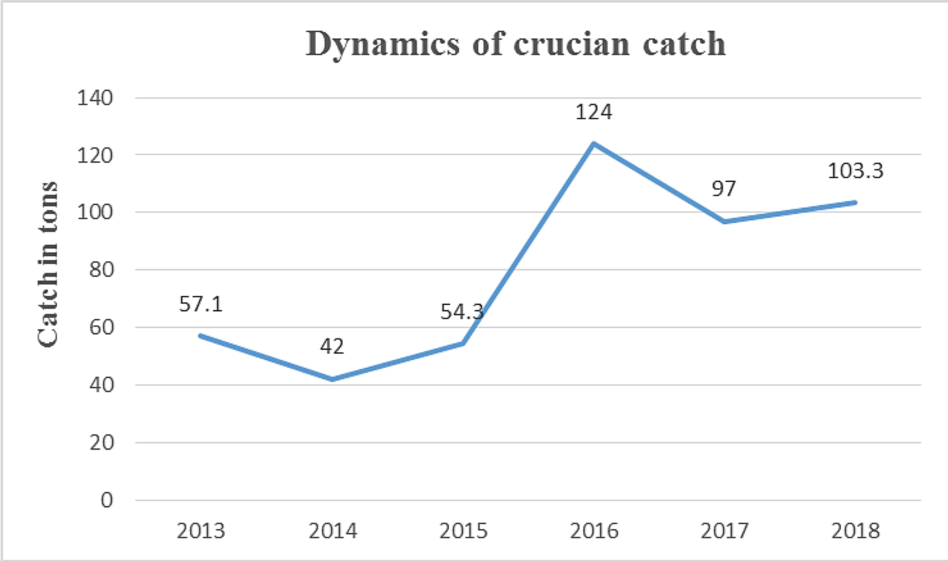

Figure 13 – The catch dynamics of crucian obtained from the river Ob

The catching number could be larger if as much attention was paid to amateur or sporting fishery. Data on amateur fishery from the river Ob shows that from 2012 to 2018, the dominating species in catches were ide, roach, and bream, as Figure 14 shows. In lakes, the more dominating species in catches were bream, crucian, and roach. There was seen to have little number of species of carp fish being caught from river Chulym.

In order to make the fishing industry significantly developed and improved in the area of Tomsk oblast, conditions of natural reproduction should be improved, some fishing rules should be strictly followed, and water bodies must be kept clean. The increase in fishing catches would be impossible without technical progress, through the mechanization and automatization of factory production, in catches as well as in processing.

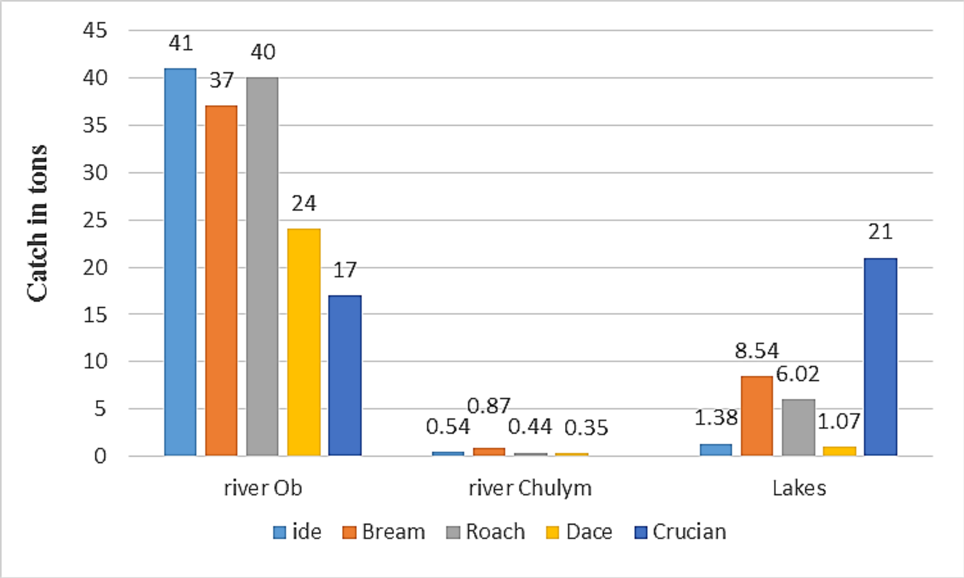

Figure 14 – The structure of amateur or sporting catches in the area of Tomsk oblast from 2012 until 2018 (in tons)

It is worth noting that based on the data analysis of Commercial and Amateur Fishery, the most predominant species of carp fish from the river Ob were ide, bream and roach, while others had lesser dominance. From 2012 until 2018, there was considerable increase in catches of the following species of carp fish: ide, dace and bream. Others had a decrease (crucian and roach).

5.2 The infestation of some commercially important species of carp fish with metacercariae *Opisthorchis felineus* (OF) in the area of Tomsk oblast

From 2017 until 2019, we were studying the infestation of some commercial species of carp fish by metacercariae *Opisthorchis felineus* (*OF*). The first species that could be infested with parasite *OF* was ide (Figure 15) because it was included in the list of the most affected species of carp fish in the rivers of Tomsk oblast based on the research conducted by Bocharova and others (2007).

The ide were being caught from the river Ob and river Tom. We examined 74 ide. According to literature, ide are actively migrated species, and that is why we analyzed both rivers together. In our catches, from 2017 until 2019, there were species at the age of 2+, 3+, 4+, 5+,6+,7+ and 8+ (mean = 5). Males were often met, and they were 82.4 % (61 specimens) at the age of 5+, (16 specimens), 6+ (12 sp.) 4+

(14 sp.), 7+ (7 sp.), 3+ (7 sp.), 8+ (3sp.), 2+ (2sp.). Female specimens were 17.5 % (13 specimens).

Figure 15 – Ide *Leuciscus idus* (Author's photo)

The maximum total length (MTL) of ide ranged from 178mm to 540mm. The average total length was 334mm. Standard length ranged from 112 to 373mm (mean = 276mm).According to linear growth rate, the ide were seen to have slight fluctuation in total length (Figure 16). Based on the data on total length, fish grew up around 30mm in a year.

Fish weight (W) was from 75 to 1290g. The average weight was 526g. According to weight growth rate, it was seen to have significant fluctuations in weight.

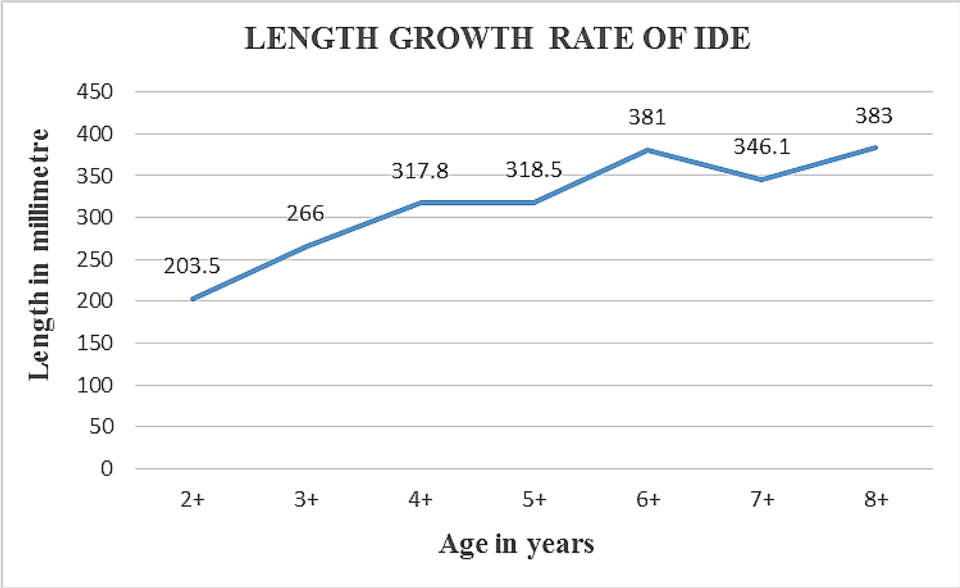

Figure 16 – Total length–age relationship of ide *Leuciscus idus* being caught from the Middle Ob basin from May in 2017 until October in 2019

Notes: both males and females were included in the analysis.

However, the general trend was to have a rise in weight with the age (Figure 17). Based on the data on W, fish gained around 117.2g in a year.

For getting accurate result, we performed statistical Kendal test, which is considered to be worked on small data and we found the statistically highly significant lack of independence between age and fish characteristics such as weight ($p < 0.001$; tau = 0.54) and length ($p < 0.001$; tau = 0.45).

The study of the interannual dynamics of infested ide with metacercariae *Opisthorchis felineus* in the Middle Ob basin showed that ide was more likely to be infested with a cat fluke from 2017 to 2018 (Figure 18). However, in 2019 there was a drop in prevalence of their infestation from 100% to 86.2%. Over the last 3 years, the prevalence in ide was 94.5%. In general, the infestation of ide has kept a higher level.

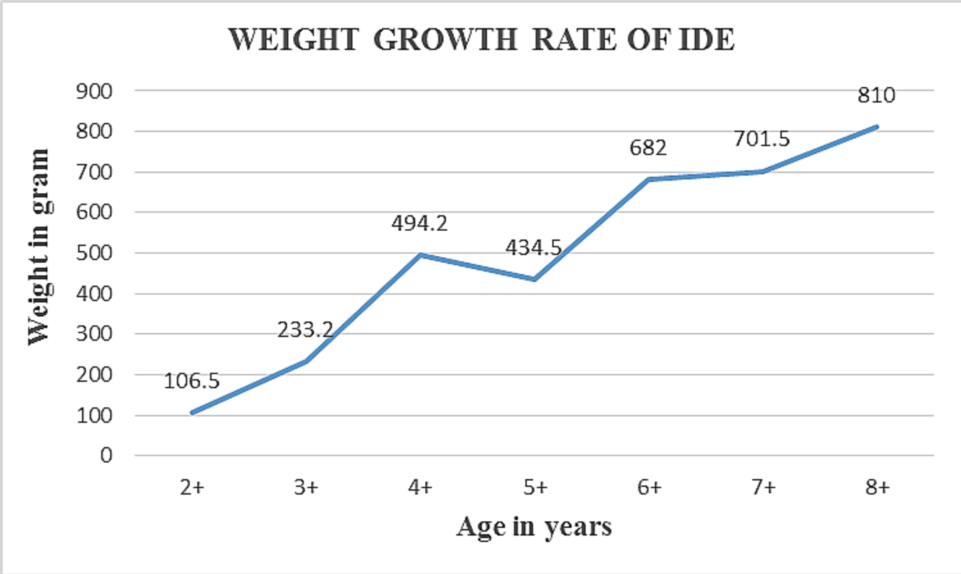

Figure 17 – Weight–age relationship of ide *Leuciscus idus* being caught from the Middle Ob basin from May in 2017 until October in 2019

Notes: both males and females were included in the analysis.

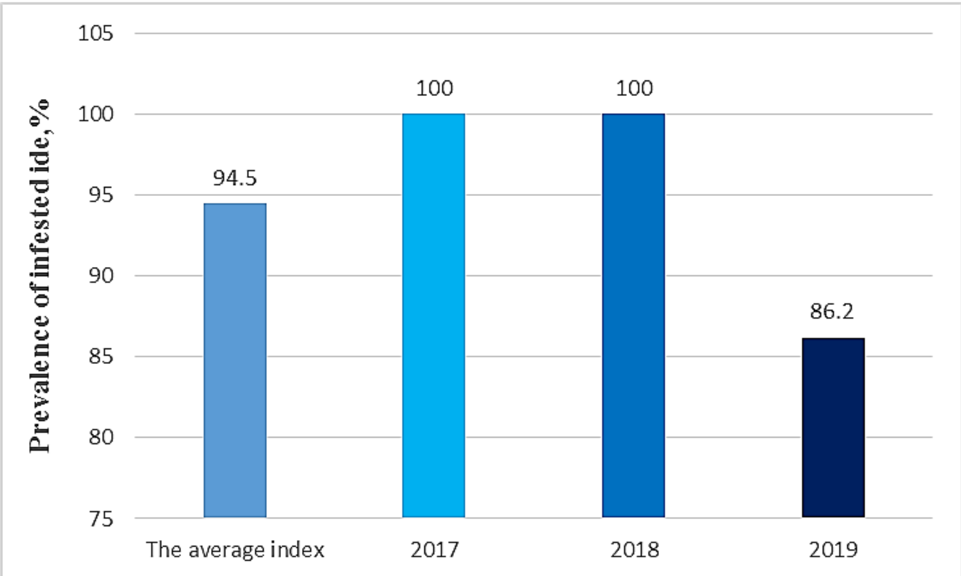

Figure 18 – Interannual dynamics of prevalence in infested ide *Leuciscus idus* with metacercariae *Opisthorchis felineus* in the Middle Ob basin from May in 2017 to October in 2019

From 2017 to 2019, the intensity of their infestation in the Middle Ob basin was 49.3±4.29 (Standard deviation (SD)) (min. number of metacercariae was 2; the max. number was 190 metacercariae in one infested specimen). The highest intensity of their infestation was in 2018, with 54.2 metacercariae found in one specimen; the lower intensity was in 2017, with 46.5 metacercariae found in one specimen, as Figure 19 clearly illustrates.

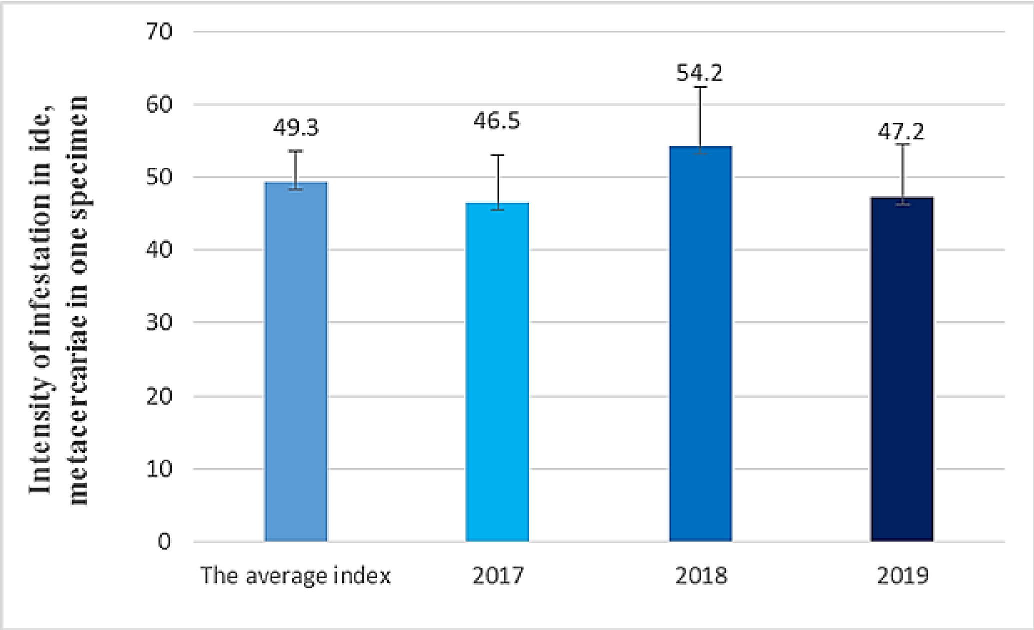

Figure 19 – Interannual dynamics of intensity of infested ide *Leuciscus idus* with metacercariae *Opisthorchis felineus* in the Middle Ob basin from May in 2017 until October in 2019

Over the last 3 years, the abundance index of ide was 46.6±4.17 (SD). The bigger abundance index was considered to be in 2018, and it was 54.2 metacercariae, while the lesser one was in 2019 – 41 metacercariae detected in one specimen (Figure 20).

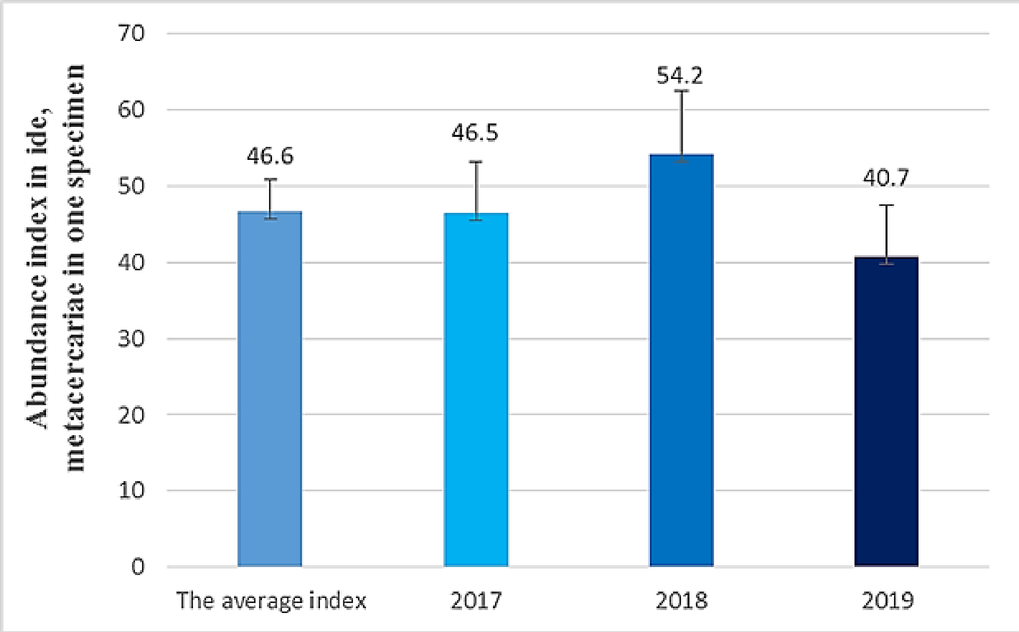

Figure 20 – Interannual dynamics of abundance index of infested ide *Leuciscus idus* with metacercariae *Opisthorchis felineus* in the Middle Ob basin from May in 2017 until October in 2019

The prevalence identified in males was 97%. Their infestation intensity was 49.6±4.82 (SD) metacercariae found in one specimen, abundance index – 48.01±4.74 (SD) metacercariae in one specimen (Figure 21; 22; 23).

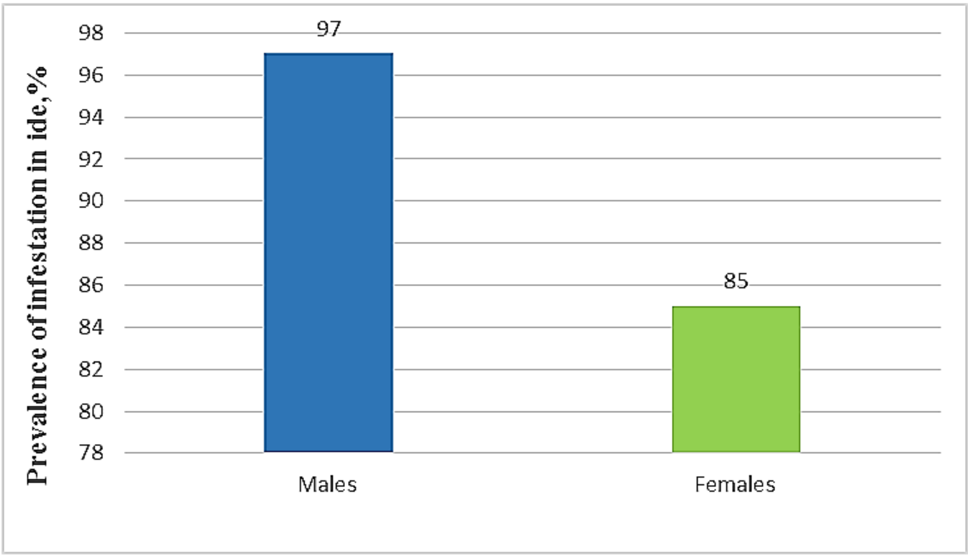

Figure 21 – Gender–related prevalence of infested ide *Leuciscus idus* with metacercariae *Opisthorchis felineus* during the period from May in 2017 until October in 2019

The prevalence of females – 85%, infestation intensity – 47.7±9.09 (SD) metacercariae found in one infested specimen, abundance index – 40.3±8.36 (SD) (Figure 21; 22; 23).

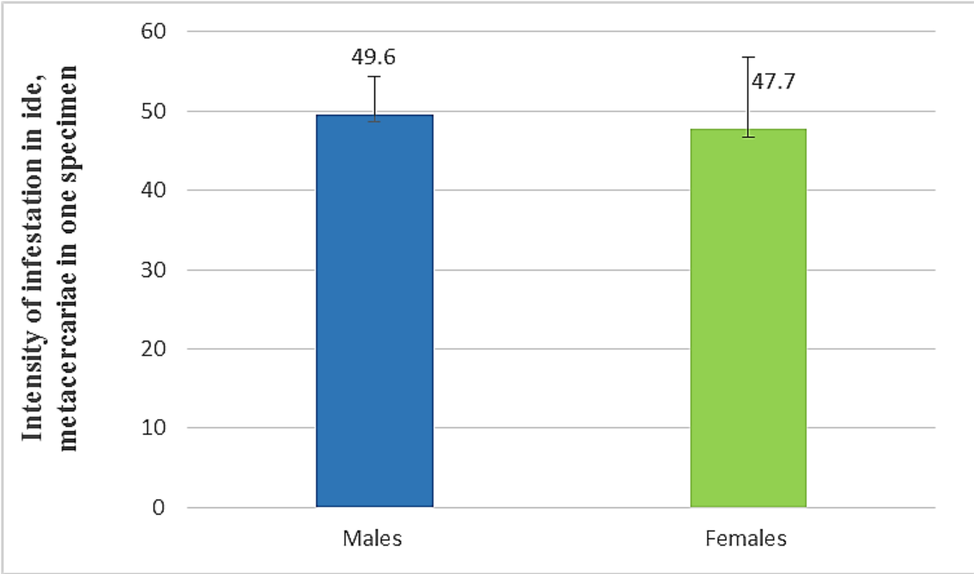

Figure 22 – Gender–related intensity of infestation of ide *Leuciscus idus* with metacercariae *Opisthorchis felineus* during the period from May in 2017 until October in 2019

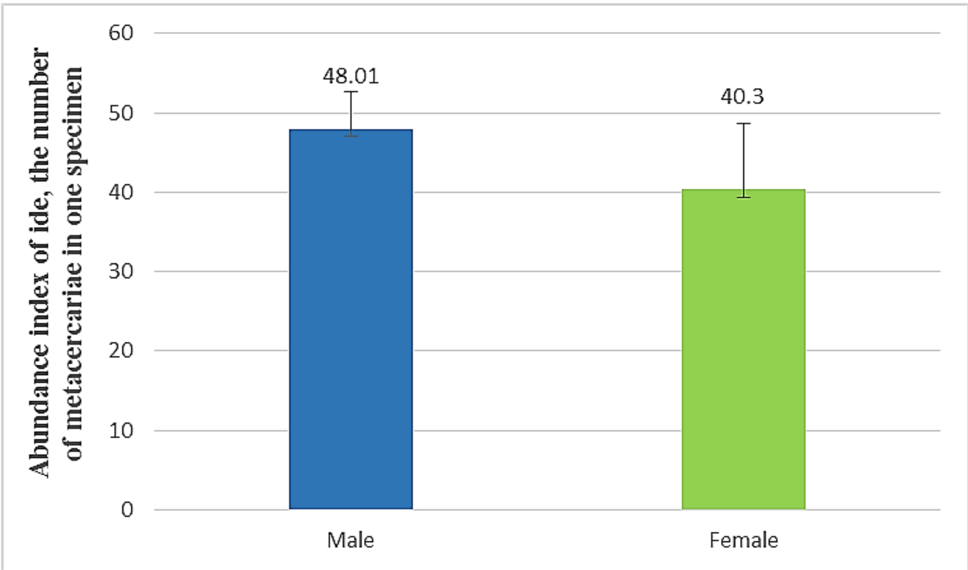

Figure 23 – Gender–related abundance index of infested ide *Leuciscus idus* with metacercariae *Opisthorchis felineus* during the period from May in 2017 until October in 2019

The analysis of age–related changes in the infestation of the ide within three years did not reveal a clear pattern. However, all mature individuals have rather high prevalence rate (Figure 24), even younger age groups. This is due to the nutrition of ide. The ide begin to feed on mollusks earlier, so they come into contact with the invasive species earlier [Экология рыб Обь–Иртышского бассейна, 2006]. There was a little number of fish at the age of 8+ (4 fish).

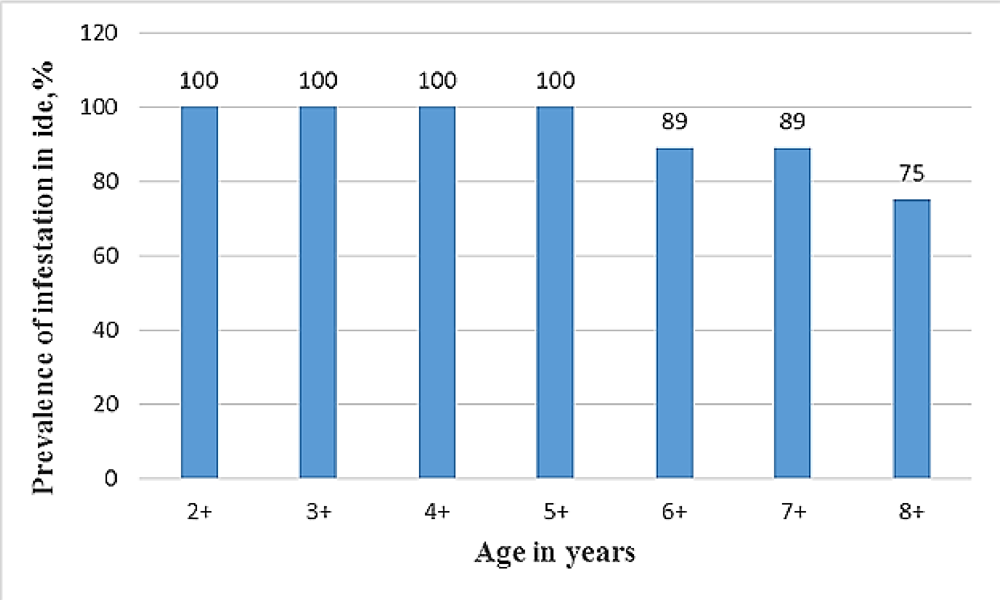

Figure 24 – Age–related prevalence of infestation in ide *Leuciscus idus* being caught from the Middle Ob basin from May in 2017 to October in 2019

The 2+–year–old specimens had intensity of infestation that was 20.5 ± 2.5 (SD), 3+–year–old specimens – 39.75 ± 8.9 (SD), 4+–year–old specimens 49.7 ± 8.3 (SD), 5+–year–old specimens – 46 ± 6.8 (SD), 6+–year–old specimens – 49.5 ± 12.4 (SD),7+–year–old – 70 ± 12.21 (SD),8+–year–old – 57 ± 22 (SD).The higher intensity of infestation was detected in specimens at the age of 4+, 6+, 7+, 8+ (Figure 25).

The 2+– year–old specimens had abundance index that was 20.5 ± 2.5 (SD), 3+–year–old specimens – 39.75 ± 8.9 (SD), 4+–year–old specimens 49.7 ± 8.3(SD), 5+–year–old specimens – 46 ± 6.8 (SD), 6+–year–old specimens – 44 ± 12 (SD), 7+–year–old specimens – 62.2 ± 11.5 (SD), 8+–year–old specimens – 42.5 ± 19 (SD).

The higher abundance index was detected in specimens at the ages of 4+, 5+, 7+ (Figure 26).

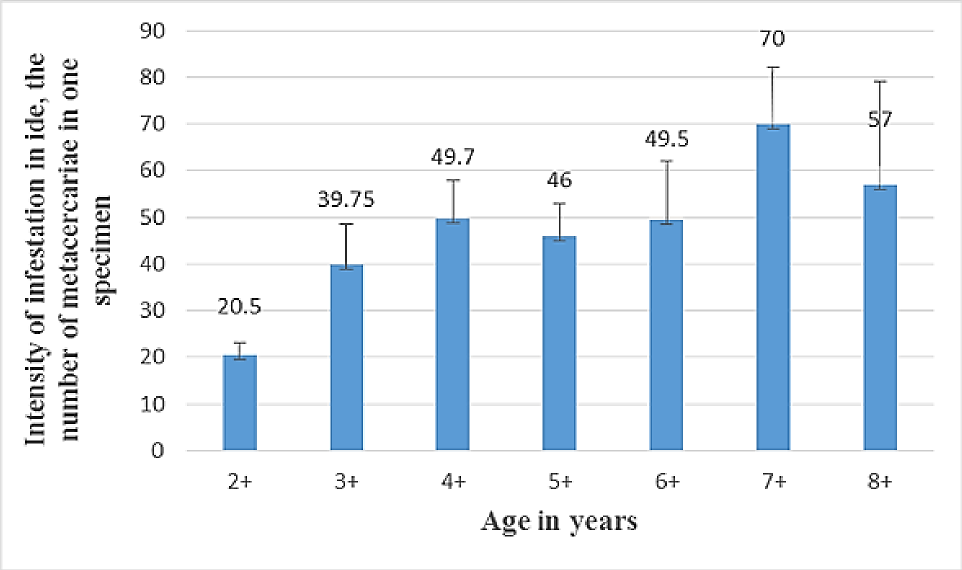

Figure 25 – Age–related intensity of infestation (metacercariae in one specimen) in ide *Leuciscus idus* being caught from the Middle Ob basin from May in 2017 to October in 2019

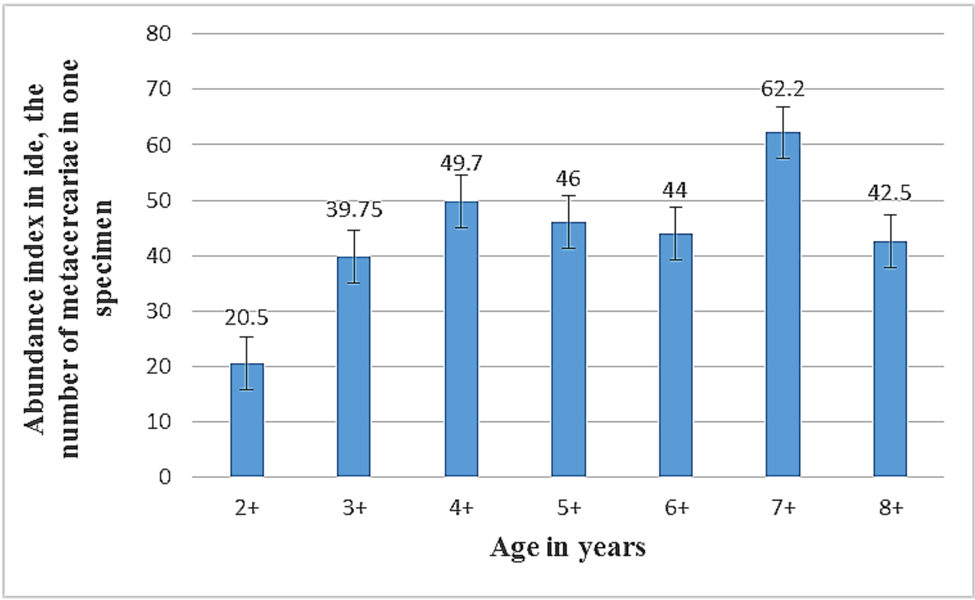

Figure 26 – Age–related abundance index (metacercariae in one specimen) in ide *Leuciscus idus* being caught from the Middle Ob basin from May in 2017 to October in 2019

The lower intensity of infestation and abundance index were identified in 2+–year–old specimens. The higher ones were in 7+–year–old specimens.

According to the earlier research conducted by Bocharova and others (2007), and Bocharova (2007), the prevalence identified in ide was quite high and ranged from 90% to 100%. The intensity of infestation ranged from 24 to 30 metacercariae found in one specimen. Thus, our investigation also showed the high infestation. The prevalence ranged from 86% to 100%, while the intensity ranged from 2 to 190 metacercariae found in one specimen.

The next species of carp fish having the commercial value in Western Siberia was dace (Figure 27). Dace was obtained from rivers such as the Ob, Tom and Basandayka. However, we analyzed dace obtained from the river Tom in the area of Tomsk oblast, because dace seldom migrates outside of another water body.

We examined 231 specimens of dace belonging to different genders and ages. We applied biological analysis to analyze the data. The predominant specimens were males that were 74.45% (170 specimens) while females were 25.5% (59 specimens). The percentage of juveniles, whose gender was not identified, was 0.8% (2 specimens). The age was up to 8+. 2+ and 3+–year–old specimens were dominating in our catch data (78 and 79 specimens).

Figure 27 – Dace *Leuciscus leuciscus* (Author: Chodkevich Nadezhda)

In our catch data, there were dace with maximum total length (MTL), which ranged from 119 to 221mm. The average length was 165mm. Standard length ranged from 97 to 179mm (mean = 135mm).The analysis of linear growth of dace related to different age groups obtained from the river Tom showed the uniform growth rate (Figure 28). From river Tom, dace grew up 16mm long in a year.

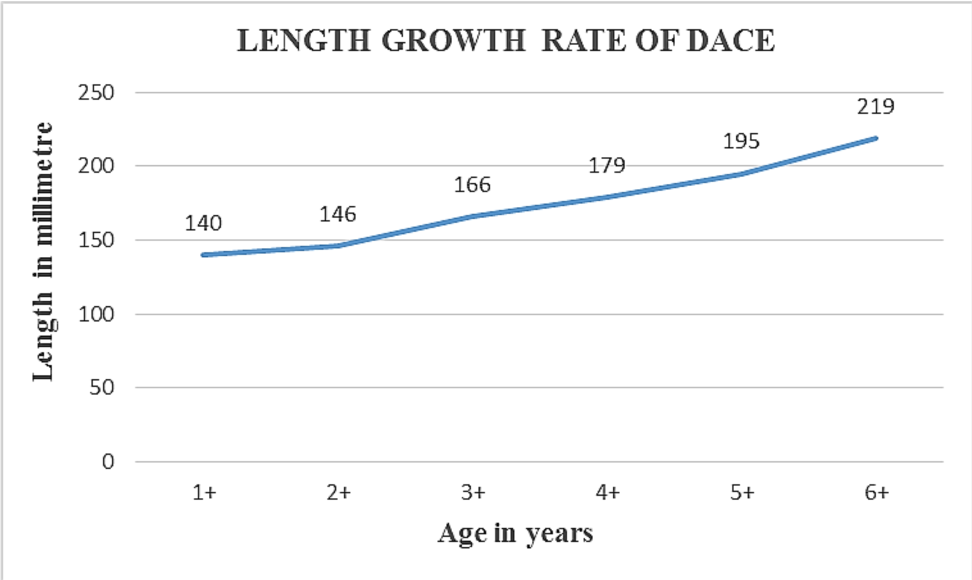

Figure 28 – Total length–age relationship of dace *Leuciscus leuciscus* being caught from river Tom from March in 2017 until September in 2019

Note: both males and females were being analyzed. Juveniles were not included in our analysis.

The weight ranged from 13 to 89g.The average weight was 39.08g. Weight growth rate in general followed linear growth (Figure 29). Based on the weight growth rate, dace grow steadily. Dace obtained from river Tom gained 8g in a year.

In both Figures 28–29, the general trend was increasing with increasing host age. Spearman analysis showed to us the highly significant relationship between the length ($p < 0.001$) and weight ($p < 0.001$) of fish and fish of different age classes. In both cases with length ($r_s = 0.78$) and weight ($r_s = 0.76$), it was seen to have strong strength of correlation between all of them (strong correlation interval's range is from 0.70 to 0.89).

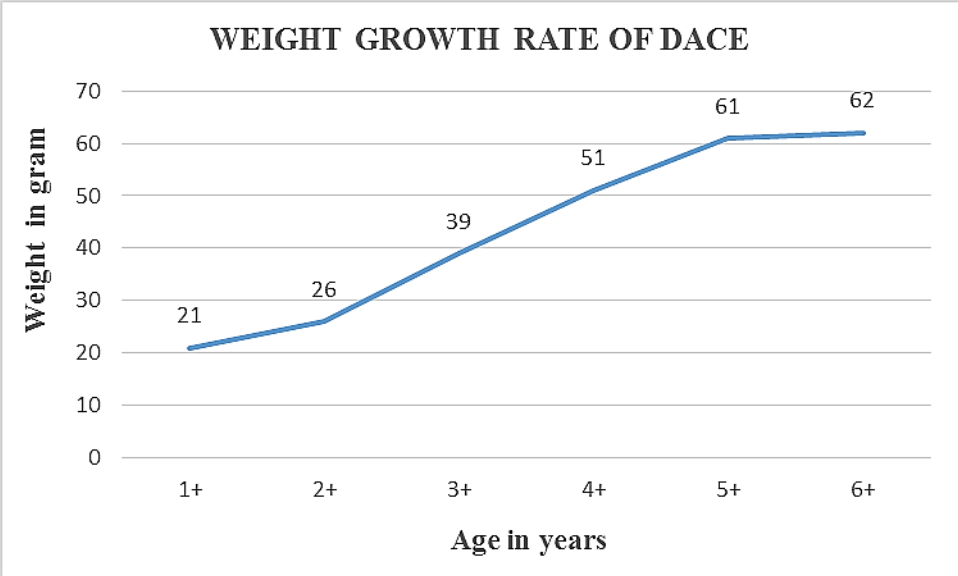

Figure 29 – Weight–age relationship of dace *Leuciscus leuciscus* being caught from river Tom from March in 2017 until September in 2019

Note: both males and females were being analyzed. Juveniles were not included in our analysis.

The study of the interannual dynamics of dace infested with metacercariae *Opisthorchis felineus* showed that from 1965 to 2003 the prevalence of their infestation increased from 19.2% to 95.7%. Then, the prevalence reduced to 76.2% in 2007. During the period from 2008 to 2013, the prevalence of infestation in dace remained constant, and it was higher than 80%. From 2014 to 2015, prevalence of their infestation had a sharp decrease to 47.8%. Then, the prevalence of their infestation increased to 96% in 2016. Over the last 3 years of conducting our research, the prevalence increased to 95.4% in 2017, and then reduced to 66% in 2019, in accordance with Figure 30.

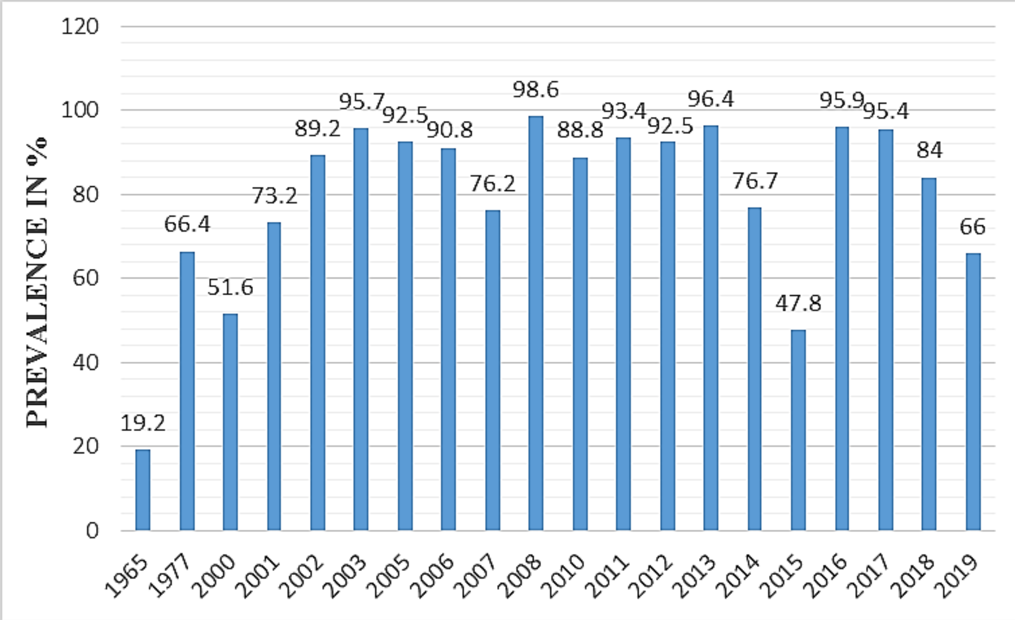

Figure 30 – Annual dynamics of infested dace *Leuciscus leuciscus* with metacercariae *Opisthorchis felineus* from 1965 until 2019 in the river Tom

Note: Data on studying infested dace from 1965 to 2016 was taken from master thesis written by Babkin A.M. (2016); from 2017 to 2019- own data

In general, the prevalence of dace infestation found in all dace from 1965 to 2019 remained high. Over the last 10 years, from 2010 to 2019, the average prevalence of their infestation remained on the level of 84%. In 2019, juveniles caught from the river Tom at the age of 2+ did not have any metacercariae.

The average intensity of their infestation within 3 years was 12.7 ± 1.23 (min. intensity – 1 metacercariae, max.intensity – 137 metacercariae found in one specimen). It significantly decreased from 16.4 ± 2.19 (SD) metacercariae in 2017 to 7.22 ± 1.18 (SD) metacercariae found in one specimen in 2019, in accordance with Figure 31.

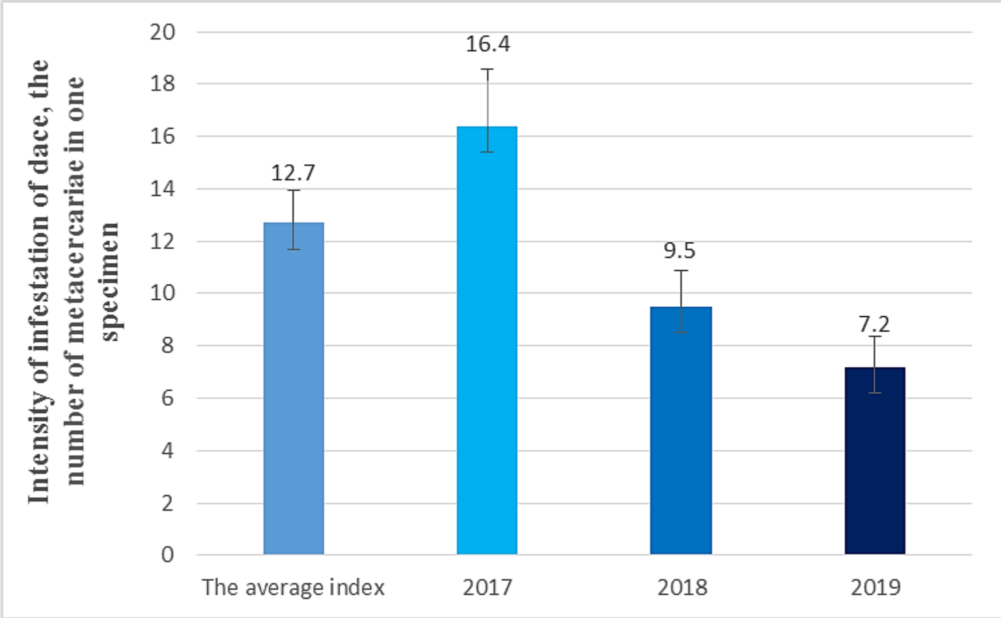

Figure 31 – The annual intensity of infested dace *Leuciscus leuciscus* with metacercariae *Opisthorchis felineus* from the river Tom

The average abundance index over the last 3 years was 10.6 ± 1.13. It ranged from 15.7 ± 2.14 (SD) metacercariae in one specimen in 2017 to 4.74 ± 0.95 (SD) metacercariae in one specimen in 2019 as Figure 32 shows.

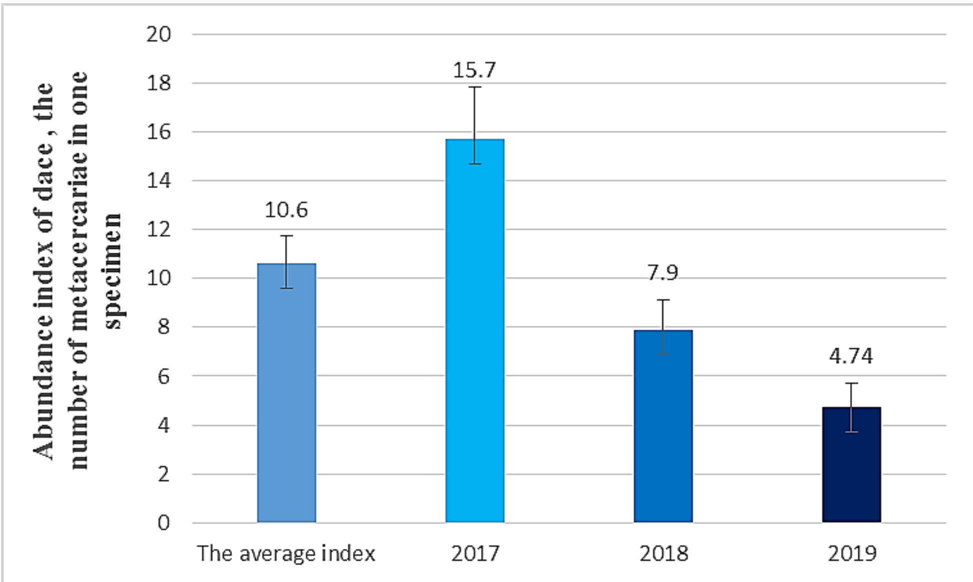

Figure 32 – The annual abundance index of infested dace *Leuciscus leuciscus* with metacercariae *Opisthorchis felineus* from the river Tom

The prevalence of infestation identified in both males and females was 85%. The prevalence of infestation in males was 83%, while 90% of prevalence was found in females in accordance with Figure 33. The average intensity of infestation in males was 12.46 ± 1.47 (SD), while females had 13.39 ± 2.3 (SD) metacercariae in one specimen (Figure 34).

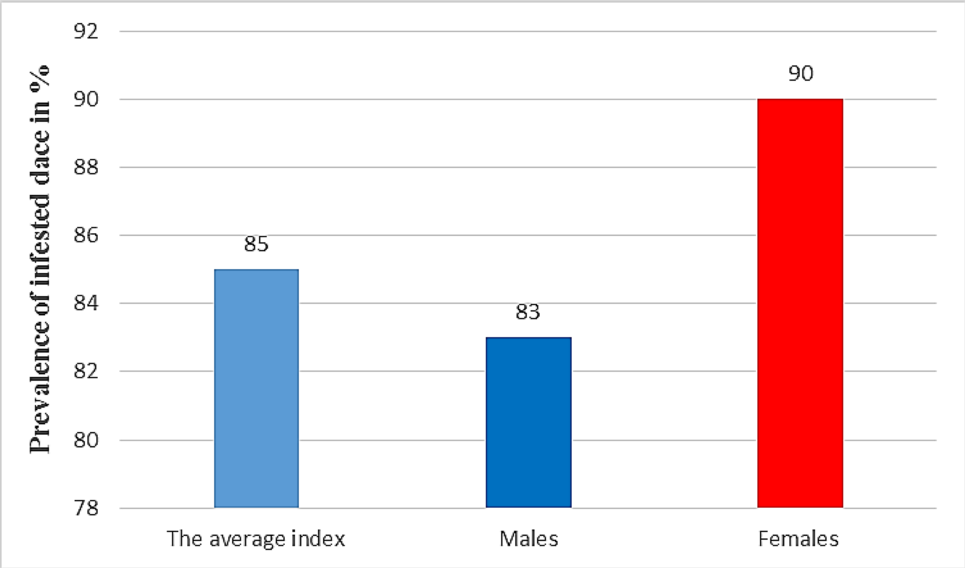

Figure 33 – Gender–related prevalence of infestation in dace *Leuciscus leuciscus* with metacercariae *Opisthorchis felineus* at the age of 1+ to 8+ from the river Tom

The average abundance index (AI) in males was 10.34 ± 1.33 (SD); in females – 12.03 ± 2.18 (SD) metacercariae in one specimen (Figure 35).

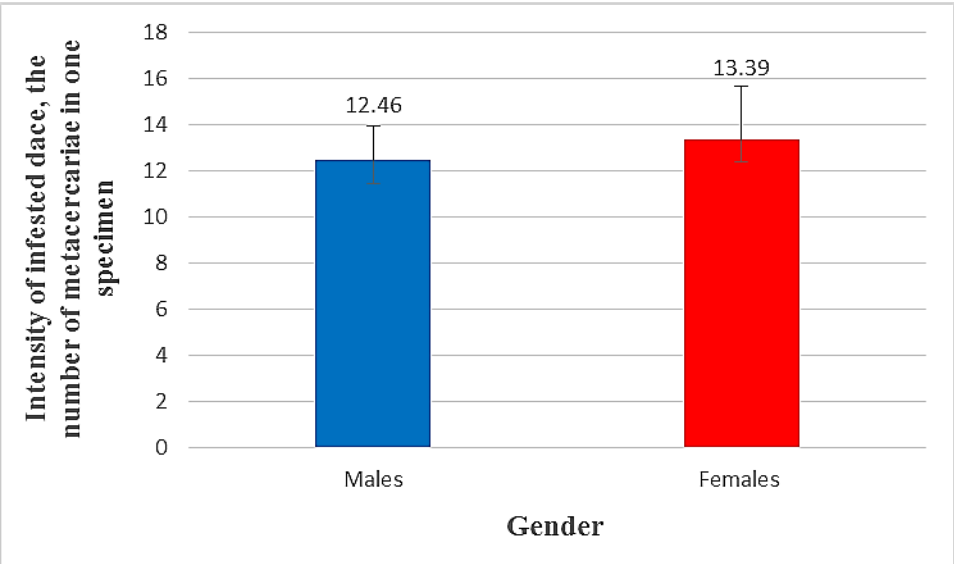

Figure 34 – Gender–related intensity of infestation in dace *Leuciscus leuciscus* with metacercariae *Opisthorchis felineus* at the age of 1+ to 8+ from the river Tom

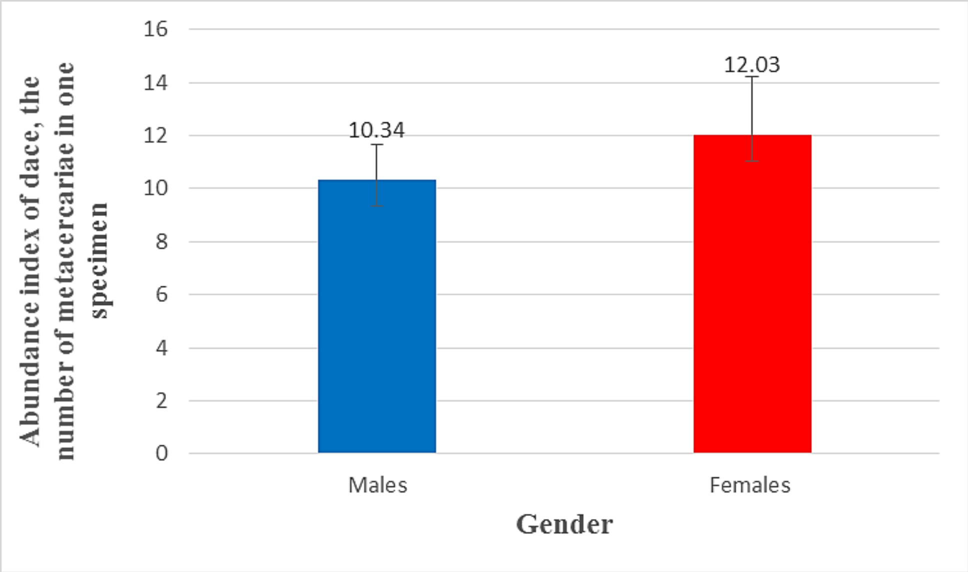

Figure 35 – Gender–related abundance index in dace *Leuciscus leuciscus* with metacercariae *Opisthorchis felineus* at the age of 1+ to 8+ from the river Tom

It was seen that higher prevalence and intensity of infestation was found in females – 90% showed signs of infestation, and they had 13 metacercariae. 83% of males showed signs of infestation, with 12 metacercariae in one specimen.

Moreover, we conducted analysis to define the infestation in different age groups of dace, from 1+ to 6+ from the river Tom. It was established that the prevalence of infestation in dace over the last 3 years, from February in 2017 to September in 2019, was 100% found in 1–year–old males and females, in 2–year–old males it was 77.7%, in females – 71.4%; 3–year–old males – 80%, in females – 100%; in 4–year–old males – 88.4%, in females – 90%; in 5–year–old males and females – 100%; in 6–year–old males – 100% in accordance with Figure 36.

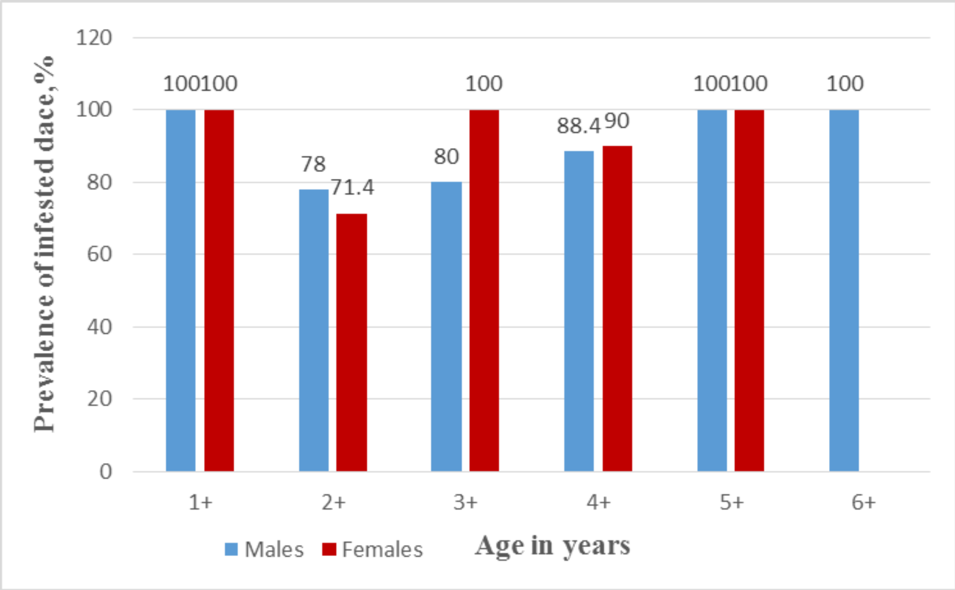

Figure 36 – Age–related prevalence of infested dace *Leuciscus leuciscus* with metacercariae *Opisthorchis felineus* from the river Tom

In general, the prevalence in different age groups of dace was quite high. The intensity of infestation in 1+–year–old males was 13.25 ± 9.7(SD) metacercariae in one specimen, in females – 3 ± 1(SD); in 2+–year–old males – 4.81 ± 0.78(SD), in females – 14.5 ± 5.2(SD); 3+–year–old males – 11.95 ± 1.91(SD), in females – 10.3 ± 2.3(SD); 4+–year–old males – 11.6 ± 1.79(SD), in females – 17.8 ± 9.01(SD) and in males at the age of 5+ – 32.8 ± 8.64(SD), in females – 13.75 ± 4.8(SD); 6+–year–old males – 55 ± 42(SD) (Figure 37).

The abundance index in 1+–year–old males was 13.25 ± 9.7(SD) metacercariae in one specimen, in females – 3 ± 1(SD); in 2+–year–old males – 3.74 ± 0.69(SD), in females – 10.3 ± 4.42(SD); in 3+–year–old males – 9.56 ± 1.7(SD), in females –10.3 ± 2.3(SD); 4+–year–old males – 10.2 ± 1.6(SD), in females – 16.1 ± 8.5(SD) and in 5+–year–old males – 32.8 ± 8.64(SD), in females – 13.75 ± 4.8(SD); in 6+–year–old males – 55 ± 42(SD) (Figure 38).

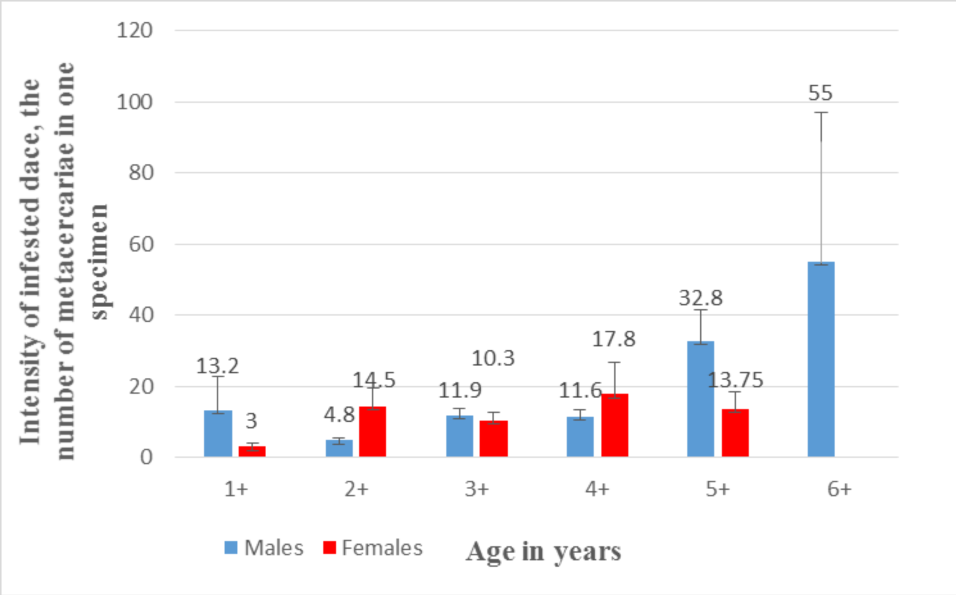

Figure 37 – Age–related intensity of infestation of dace *Leuciscus leuciscus* with metacercariae *Opisthorchis felineus* from the river Tom

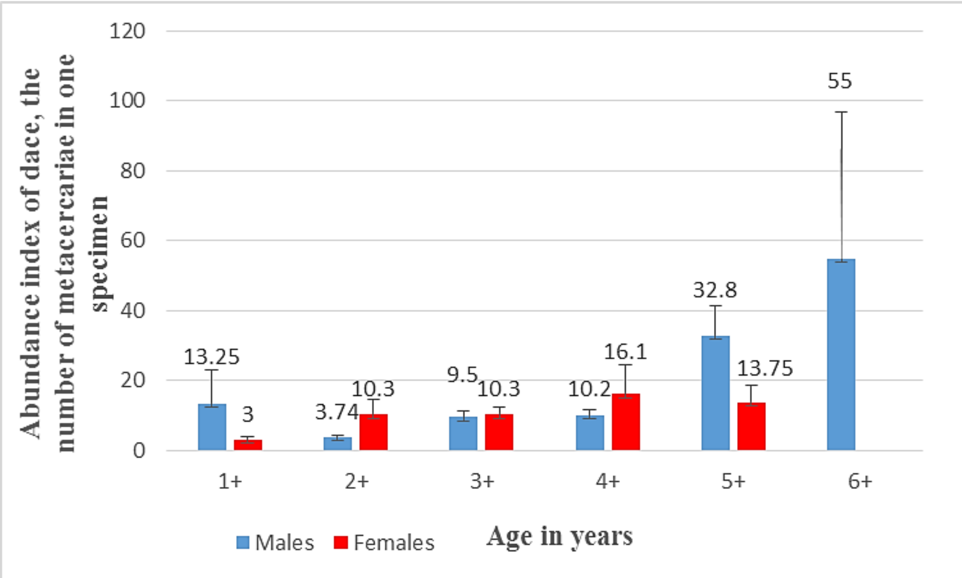

Figure 38 – Age–related abundance index of infested dace *Leuciscus leuciscus* with metacercariae *Opisthorchis felineus* from the river Tom

Based on the figures mentioned above, parasite infestation (number of parasites) showed the trend of increasing with increased age. The Spearman rank correlation test demonstrated a very strong evidence to believe in the relationship between infestation and fish related to different age groups (p < 0.001) with the moderate confidence $r_s = 0.43$, corrected for ties (95% confidence intervals = 0.40 to 0.69).

In addition to that, this Spearman correlation test showed the very strong relationship between length ($p < 0.001$), weight ($p < 0.001$) and infestation with the moderate strength of correlation ($r_s = 0.42$).

A decrease of infestation in dace is explicitly observed in comparison with the previous research, such as one of those conducted by Bocharova T.A. and others (2007) and Bocharova T.A. (2007). Based on their research conducted in 2007, the prevalence of infestation reached 92%, while the intensity ranged from 1 to 120 metacercariae found in one specimen.

In our research, the range of prevalence of infested dace was from 66 to 95.4% (the average was 85%). The range of their infestation intensity was from 1 to 137 metacercariae found in one infested specimen. Despite having a drop in infestation, dace is still being affected by this parasite *Opisthorchis felineus*, and it is established to be one of the carriers of parasite *Opisthorchis felineus* in the Middle Ob basin.

The next species that is worth considering is bream, an introduced species expanding the cycle of hosts carrying metacercariae *Opisthorchis felineus* [Интересова и др., 2017; Симакова и др., 2018; Симакова и др., 2019] (Figure 39).

In our catches, there were 146 bream. There were specimens at the age of up to 8+. 1+–year–old specimens were found often, and the number of them was 78. There were 2 juveniles at the age of 1+. The percentage of males was 69% (98sp.), while of females it was 31% (43sp.).

Figure 39 – Bream *Abramis brama* (Author’s photo)

Three specimens were taken out from the river Tom and that is why we paid much attention to the dominant catch obtained from river Ob (141 specimens). We have analysed males and females. Juveniles have not been included in our analysis. The maximum total length (MTL) ranged from 86mm to 443mm (mean = 176mm), the maximum standard length (MSL) was from 71 to 345mm (mean = 135mm). Their weight ranged from 7g to 912g (mean = 98g) (Figure 40; 41).

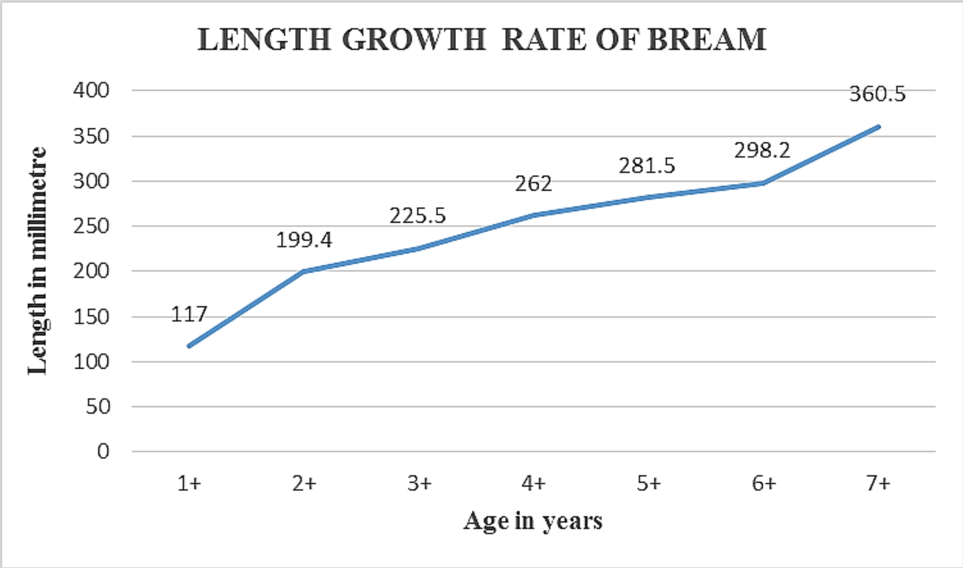

Figure 40 – Total length–age relationship of bream *Abramis brama* being caught from river Ob from January in 2017 until October in 2019

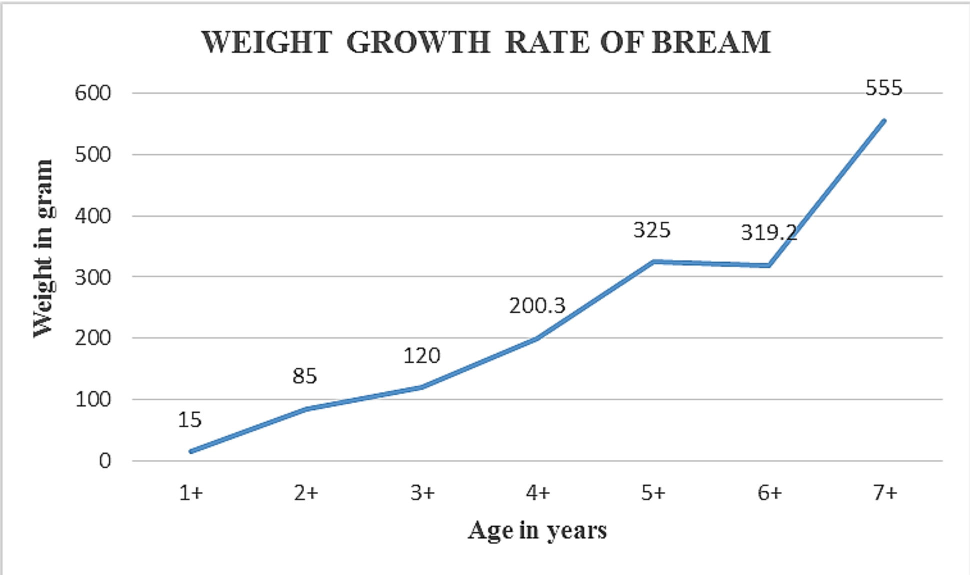

Figure 41 – Weight–age relationship of bream *Abramis brama* being caught from river Ob from January in 2017 until October in 2019

The average growth rate for a year was 40.5mm. The average weight growth was 90g (Figure 40; 41).

As the Figure 40 and Figure 41 suggest, length and weight increased with increasing age and their relationship with age was statistically significant ($p < 0.001$) with very strong strength of correlation ($r_s = 0.86$ with the confidence interval = 0.70 to 0.89) based on the Spearman correlation test.

The analysis of their infestation by liver fluke showed that the prevalence of their infestation was 2.05%. During our research, conducted from 2017 to 2019, there were 3 infested specimens with metacercariae *Opisthorchis felineus*, of which 2 of them were 3–year–old males, while the last one was a 7–year–old female. The intensity of their infestation was 2 ± 0.2 (SD) metacercariae found in one specimen, with abundance index – 0.04 ± 0.02(SD) metacercariae in one specimen (Table 7).

Table 7 – Parametric data and infestation of bream with liver fluke *Opisthorchis felineus*

Type	Age	Gender	MTL,mm	MSL,mm	W,g	O.F	Date
Bream	3	Male	215	170	105	1	July 2018
Bream	3	Male	199	150	60	1	May 2019
Bream	7	Female	400	235	723	4	June 2019
Note: MTL – maximum total length; MSL – maximum standard length; W – weight; O.F – *Opisthorchis felineus* (liver fluke)							

Previous research did not detect any *Opisthorchis felineus* in this species from the Middle Ob basin. All observed specimens were not affected by this parasite [Соусь, Ростовцев, 2006; Бочарова, 2007]. The prevalence of infestation in bream was 2.05%, while the intensity was from 1 to 4 metacercariae found in one specimen. It is worth noting that despite having no higher infestation rate, bream must be included in the list of carp fish participating in the life cycle of the parasite, leading to the spreading of disease in the Middle Ob basin, in the area of Tomsk oblast.

The third species that has commercial value is roach. There were 243 specimens of roach (Figure 42). There were 159 males (65.4%), 74 females (30.45%), 10 juveniles (4.11%). The age was up to 7+. There were 53 specimens at the age of 3 who were more dominant in our catch than the others. The MTL was from 95 to 265mm (mean = 163mm). Maximum standard length ranged from 48 to 214mm (mean = 132mm). The W was from 8g to 240g (mean = 49g).

Figure 42 – Roach *Rutilus rutilus* (Author: Chodkevich Nadezhda)

In general, the total length in roach caught from the Middle Ob basin was even. The general trend was an increase in length and weight with age. The average growth rate in whole catch was 24mm, as shown by Figure 43. The average growth was 30g from the river Ob (Figure 44).

As the linear and weight growth rate showed, the trend was an increase in length and weight with age. Non-parametric Spearman correlation test showed a very strong evidence ($p < 0.001$) to believe in their relationship with strong correlation between length ($r_s = 0.79$ with confidence interval = 0.70 to 0.89) and weight ($r_s = 0.81$) in accordance with fish age.

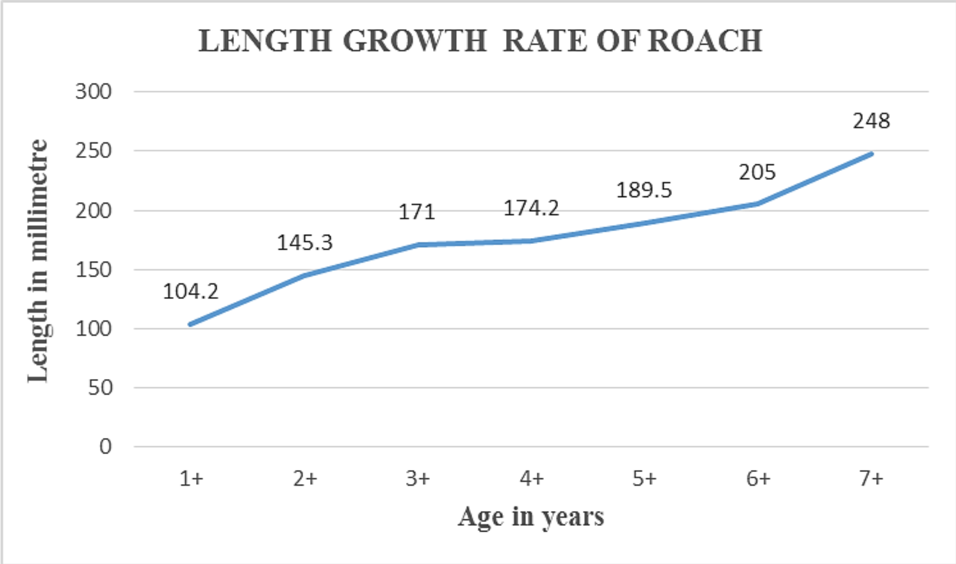

Figure 43 – Total length–age relationship of roach *Rutilus rutilus* being caught from the Middle Ob basin from January in 2017 until July in 2019

Note: Juveniles have not been included.

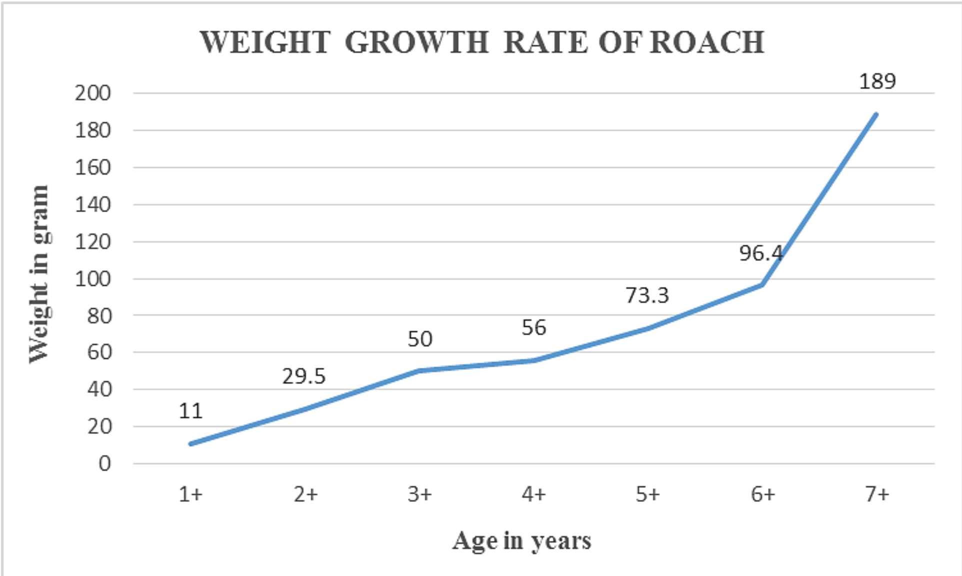

Figure 44 – Weight–age relationship of roach *Rutilus rutilus* being caught from the Middle Ob basin from January in 2017 until July in 2019

Note: Juveniles have not been included.

The average prevalence of infested roach was 1.23%. The specimens in which there were metacercariae were 3. Two of them were a 3+–year–old female and male, and one was a 4+–year–old male, as Table 8 illustrates. The average intensity was 4 ±

0.29 (SD) metacercariae in one specimen, while the abundance index was 0.04 ± 0.03 (SD) metacercariae in one specimen.

Table 8 – Parametric data and infestation of roach with liver fluke *Opisthorchis felineus*

Type	Age	Gender	MTL,mm	MSL,mm	W,g	O.F	Date
Roach	3	Female	200	166	72	7	January 2017
Roach	4	Male	173	140	54	2	February 2019
Roach	3	Male	172	144	53	3	February 2019

Note: MTL – maximum total length; MSL – maximum standard length; W – weight; O.F – *Opisthorchis felineus* (liver fluke).

Earlier research conducted by Bocharova T.A. and others (2007) and Bocharova T.A (2007) dedicated to detecting parasites in roach talked about a decrease in infestation from 15% to 8.5%. The intensity of infection was from 1 to 2 parasites in one specimen. Thus, our investigation also shows the decrease in their infestation from the river Ob. The prevalence was 1.23%, the intensity ranged from 2 to 7 metacercariae in one specimen. Despite having a decrease, this species is also still participating in the life cycle of the parasite, leading to spreading disease Opisthorchiasis along the territory of the Ob–Irtysh basin.

The next species with commercial value was crucian (Figure 45). There were 74 crucian with different age groups and genders. There were 23 females (31%) and 51 males (69%). Crucians were being caught from the following lakes: Kerepet' and Igumen.

The Maximum Total length (MTL) of observed specimens ranged from 123 to 425mm (mean = 178.2mm). The maximum standard length (MSL) ranged from 98 to 274mm (mean = 144mm).

The weight was from 34 to 1299g (mean = 165.3g) (Figure 46; 47). The average growth rate in the whole catch was 29mm. The average weight rate was 94g.

Figure 45 – Crucian *Carassius gibelio* (Author's photo)

We performed Kendal correlation test that is non-parametric test dedicated to working with small data. As Kendal correlation test showed that length ($p < 0.001$; tau = 0.45) and weight ($p < 0.001$; tau = 0.50) were moderately correlated with age.

Earlier research conducted by Pel'gunov (2010) dedicated to finding *Opisthorchis felineus* in crucians did not reveal any parasites.

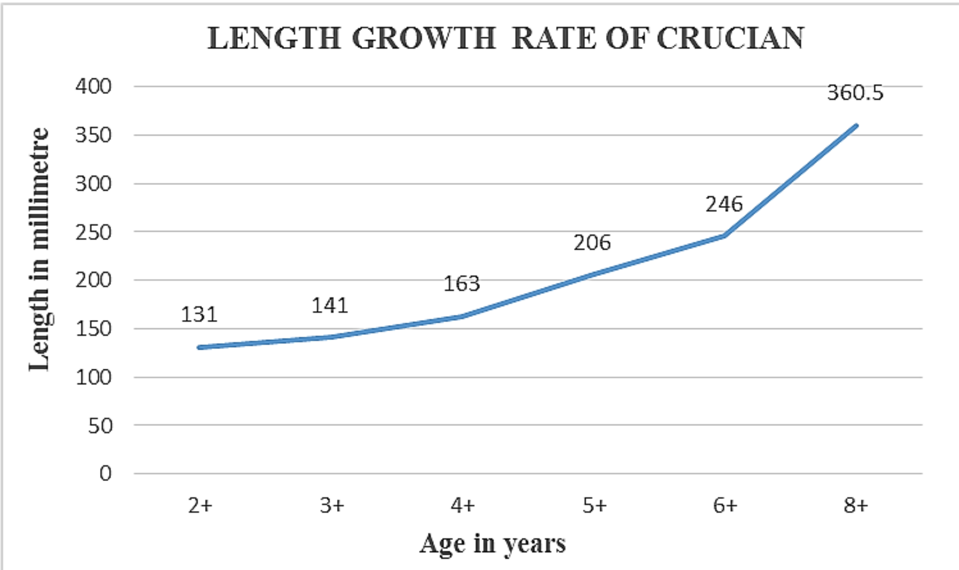

Figure 46 – Total length–age relationship of crucian *Carassius gibelio* being caught from lake Kerepet' and lake Igumen from November in 2018 until June in 2019

According to the Pel'gunov's findings, it could be a good evidence of their insensitivity in relation to being infested with a cat fluke. Their inclusion in the list of parasite carriers could be incorrect. Therefore, our research shows the same results as has been shown in previous years.

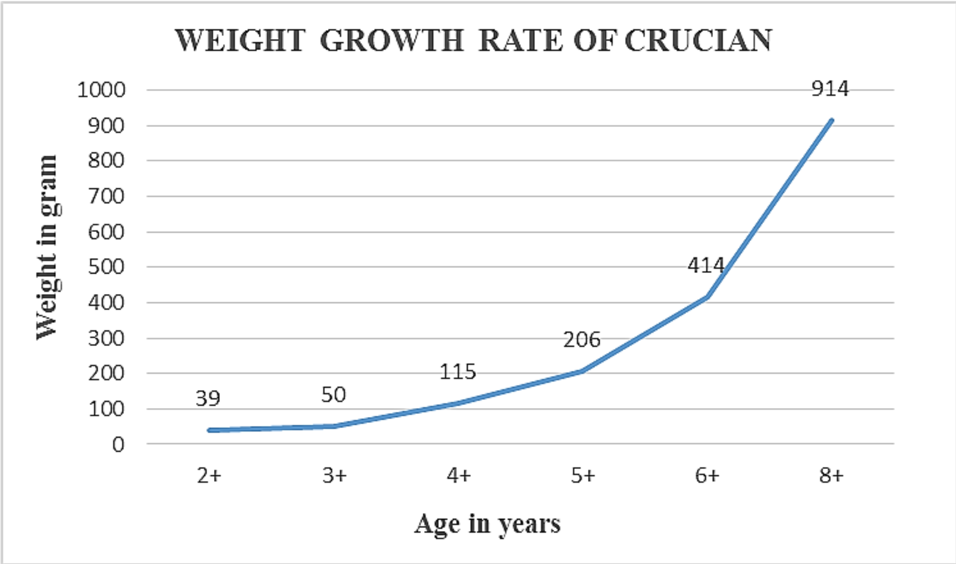

Figure 47 – Weight–age relationship of crucian *Carassius gibelio* being caught from lake Kerepet' and lake Igumen from November in 2018 until June in 2019

It can plainly be seen from the obtained results that absolutely all of the fish besides crucian were being affected by the parasite *O. felineus*. The prevalence in ide reached 94.5%; in dace – 85%; in bream – 2.05%; in roach –1.23%.

The intensity of infestation in ide was 49.3; in dace – 12.7; in bream – 2, in roach – 4 metacercariae in one specimen. The highest intensity of infestation in ide was 190; in dace – 137 metacercariae in one specimen. The lowest intensity of infestation in ide was 2 larvaes in one specimen; in dace – 1 larvae in one specimen. Crucian did not have any parasites.

Thus, the infestation of roach and bream were lesser than in comparison with earlier research. The main carriers of the parasite *O. felineus* in the area of Tomsk oblast were ide and dace. The results allowed us to conclude that ide, dace, bream and roach are still being infested, which could be leading to spread disease Opisthorchiasis among people living along the Middle Ob basin.

CONCLUSION

1. Over the last 10 years in Tomsk oblast, a decrease in intense incidence rate of population from 239.3 in 2009 to 130.6 per 100,000 people in 2019 was seen. However, the overall infestation level remained quite high.

2. More infested people are considered to live in the following northern districts of Tomsk oblast: Alexandrovskyi (607), Kargasokskyi (484), Tegul'detskyi (368), Asinovskyi (239),Kolpashevskyi (121), Tomskyi (114). Fewer infested people live in southern districts, such Molchanovskyi (98), Verkhneketskyi (86), Zyryanskyi (61), Kozhevnikovskyi (56), Chainskyi (54), Parabel'skyi (38), Shegarskyi (17), Kryvosheenskyi (14), Pervomaiskyi (6).

3. In the Middle Ob basin, there are 13 species of carp fish, of which 5 are commercial species: ide, dace, bream, roach and crucian. The dominant species in the river Ob are roach (277 tons), ide (275 tons) and bream (266 tons); less dominant species in catches are crucian (68.2 tons) and dace (60.3 tons).

4. The Infestation level in ide obtained from the Middle Ob basin has maintained a high level. The average prevalence was 94.5% (ranged from 86% to 100%). The intensity of infestation averaged 49 metacercariae in one specimen, ranging from 2 to 190 metacercariae in one infested specimen.

5. The average prevalence of infested dace over the last 3 years was 85%. The prevalence ranged from 66% to 95.4%. The average infestation intensity was 12 metacercariae found in one infested specimen. It ranged from 1 to 137 metacercariae in one specimen.

6. As the example about dace showed, infestation level was dependent on age, length, and weight of fish. This is because of accumulating parasites in the fish muscles.

7. The infestation identified in roach and bream was not high. The infestation prevalence in bream was 2.05%, while in roach it was 1.23%. The average infestation intensity in bream was 2 metacercariae, while in roach it was 4

metacercariae found in one infested specimen. Crucian has not been found to be infested with metacercariae *Opisthorchis felineus*.

8. In the Middle Ob basin in the area of Tomsk oblast, the main carriers of metacercariae *Opisthorchis felineus* are currently ide and dace.

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АНТИПЛАГИАТ
ТВОРИТЕ СОБСТВЕННЫМ УМОМ

Отчет о проверке на заимствования №1

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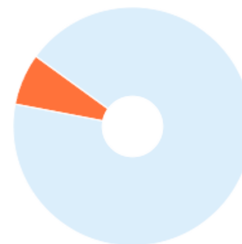
Отчет предоставлен сервисом «Антиплагиат»- http://users.antiplagiat.ru

ИНФОРМАЦИЯ О ДОКУМЕНТЕ

№ документа: 2
Начало загрузки: 08.06.2020 03:21:12
Длительность загрузки: 00:00:03
Имя исходного файла: infestation of some commercially important species of carp fish with Opisthorchis felineus in the middle ob basin.pdf
Название документа: infestation of some commercially important species of carp fish with Opisthorchis felineus in the middle ob basin
Размер текста: 1 кБ
Символов в тексте: 104809
Слов в тексте: 15237
Число предложений: 1154

ИНФОРМАЦИЯ ОБ ОТЧЕТЕ

Последний готовый отчет (ред.)
Начало проверки: 08.06.2020 03:21:15
Длительность проверки: 00:00:08
Комментарии: не указано
Модули поиска: Модуль поиска Интернет



ЗАИМСТВОВАНИЯ 7,22%
САМОЦИТИРОВАНИЯ 0%
ЦИТИРОВАНИЯ 0%
ОРИГИНАЛЬНОСТЬ 92,78%

Заимствования — доля всех найденных текстовых пересечений, за исключением тех, которые система отнесла к цитированиям, по отношению к общему объему документа.
Самоцитирования — доля фрагментов текста проверяемого документа, совпадающий или почти совпадающий с фрагментом текста источника, автором или соавтором которого является автор проверяемого документа, по отношению к общему объему документа.
Цитирования — доля текстовых пересечений, которые не являются авторскими, но система посчитала их использование корректным, по отношению к общему объему документа. Сюда относятся оформленные по ГОСТу цитаты; общеупотребительные выражения; фрагменты текста, найденные в источниках из коллекций нормативно-правовой документации.
Текстовое пересечение — фрагмент текста проверяемого документа, совпадающий или почти совпадающий с фрагментом текста источника.
Источник — документ, проиндексированный в системе и содержащийся в модуле поиска, по которому проводится проверка.
Оригинальность — доля фрагментов текста проверяемого документа, не обнаруженных ни в одном источнике, по которым шла проверка, по отношению к общему объему документа.
Заимствования, самоцитирования, цитирования и оригинальность являются отдельными показателями и в сумме дают 100%, что соответствует всему тексту проверяемого документа.
Обращаем Ваше внимание, что система находит текстовые пересечения проверяемого документа с проиндексированными в системе текстовыми источниками. При этом система является вспомогательным инструментом, определение корректности и правомерности заимствований или цитирований, а также авторства текстовых фрагментов проверяемого документа остается в компетенции проверяющего.

№	Доля в отчете	Источник	Ссылка	Актуален на	Модуль поиска
[01]	1,09%	http://vital.lib.tsu.ru/vital/access/services/Download/vital:4261/SOURCE01	http://vital.lib.tsu.ru	22 Июл 2019	Модуль поиска Интернет
[02]	1,68%	Download .pdf	http://sevin.ru	18 Мая 2020	Модуль поиска Интернет
[03]	0,53%	Анализ заболеваемости инвазией Opisthorchis felineus и злокачественн…	https://cyberleninka.ru	05 Мая 2020	Модуль поиска Интернет

Еще источников: 17
Еще заимствований: 3,92%