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# Pike *Esox Lucius* Distribution and Feeding Comparisons in Natural and Historically Channelized River Sections

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***Abstract* – During the last century a large portion of small and medium-sized rivers in Latvia were channelized, hydroelectric power stations were also built, which led to changes in the hydrodynamic conditions, geomorphological structure, as well as a change in the fish fauna. Fish are an integral part of any community in natural or man-made bodies of water. They actively participate in maintaining the system, balancing/equilibrium, energy, substance transformation and biomass production. They are able to influence other organisms in the ecosystem in which they live. The aim of the paper "Pike distribution and feeding comparisons in natural and historically channelized river sections" is to find out what pike feed on in different environments in Latvian rivers, such as natural and straightened river sections, as well as what main factors determine the composition of their food. Several points were assessed during the course of the study: the impact of environmental conditions on the feeding habits and the distribution of pike; the general feeding habits of predators in Latvian rivers; the feeding differences of predators in natural and straightened river sections; and lastly, rhithral and pothamal habitats were compared. The study was based on data from 2014 and 2015 on fish fauna monitoring. During the study, 347 pike were collected from 136 plots using electrofishing method.**

***Keywords* – Pike; feeding; pothamal; channelized; river**

## 1. INTRODUCTION

Water is one of the most important natural resources, but human activity is directly threatening freshwater resources, and due to climate change, this exacerbating the problem. Freshwater resources are particularly effect by changes in land usage, industrialization, urbanization, irrigation, and the formation of reservoirs and channels [1]. Such activities homogenize the hydraulic and geomorphological characteristics of streams. This results in a decrease in the amount of species, their incidence and prevalence in certain areas, which ultimately negatively affects the function of the ecosystem [2], [3]. One of the best examples of Latvia in this context are the Daugava River. In which in last century from year 1939 to 1974 were built three hydro power plants, which adversely affected the river flow, completely destroyed riffle structure, completely end migration of diadromous species, altered the distribution of species in Daugava River basin [4].

The result of river straightening has an immediate impact on river flow and a destroyed habitat structure, but the most important point is that there is a long-term biotic change that affects all taxonomic levels in channelized river sections [5]. Straightening rivers prevents the flooding of floodplains during heavy rain and reduces the amount of erosion in the channelized sections; but it intensifies it in another area. It increases the likelihood of danger in the lower reaches of the river

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due to the increased velocity of the mass of water higher upstream, it reduces the amount of mosaic structures related to meanders, as well as reactivating suspended particles from the river bed [6].

A particularly sensitive biological quality element in rivers are fish fauna, because it will react to anthropogenic impact caused problems including, chemical pollution, eutrophication, acidification, habitat transformations, and changes in river flow [7]. The community of a fish species, the amount of species and their distribution, and the biomass, in a specific body of water characterizes the quality of its productivity. Fish fauna tend to be a better indicator of the quality of a river since they involve a cumulative chemical, physical, temporal and spatial effect [8].

Anthropologically modified straightening of rivers significantly reduces the number of species of fish biomass. Diversity decreases by as much as 60 %, while the biomass of fish – by even several times more [9]. It is estimated that of the 139 major river systems in the world, 77 % are medium or heavily modified by dams, reservoirs, irrigation systems, and deviations [10]. This river fragmentation creates barriers for fish migration, and changes flow patterns and water temperatures. As a result of fragmentation there is reduced habitat diversity, for example, a reduced amount of rapids. Smaller structures such as bridges or culverts may affect fish movement during low water periods [9]. According to data by the Latvian Environment, Geology and Meteorology Centre (LEGMC), 27.1 % of Latvian river water bodies have significantly been morphologically modified [11].

Pike is the main predator in many northern hemisphere, temperate zone, freshwater habitats, and estuarine ecosystems, and it is a key species in ecosystems in both European and North [12]–[14] functioning fish communities, because it determines the fish community structure and species composition. It also is an important species for both recreational and commercial fisheries [15]. Fish feeding ecology of the water body can significantly affect the trophic structure and productivity [16], [17]. Pike, as a predator, particularly effect the previously mentioned anthropogenic impacts [18], [19].

## 2. METHODOLOGY

### *2.1. The Area of Study, Time, and Characteristics*

The field study was conducted throughout the Latvian territory in 2014 and 2015 during the summer season (June–August). The Latvian river fish fauna monitoring carried out by the Institute of Food Safety, Animal Health and Environment BIOR included: salmon, fish background monitoring, and the inspection of Natura 2000 sites. During the study period, pike stomachs were harvested from 136 plots in 64 rivers (Fig. 1).

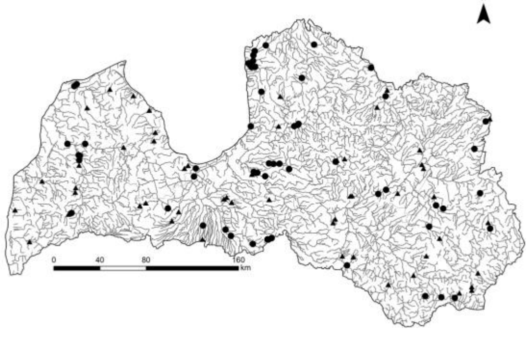


Fig. 1. Pike stomach collection places (● – natural river sections ▲ – cannalized sections) [20], [21].

### *2.2. Plot Selection and Characterization*

The fauna sampling in rivers took place in the summer months when the water level is the lowest and has a relatively high water temperature, which increases the efficiency of electrofishing. The plots in the rivers were chosen so that the attainable data fully represented each surveyed rivers fish communities, including greater microhabitat diversity. Several measurements and assessments of environmental parameters were made at the fish tracking sites, which were noted in the original form provided for field work. Data will be recorded on the fishing place and time, coordinates of fishing grounds; water parameters are recorded with the HANNA HI9828 multiparameter probe, the current velocity measure with the FP 201 Global Flow Probe meter, and a description of the fishing grounds, the riverbed substrate characteristics, etc.

### *2.3. Fish Sampling With Electrofishing.*

Electrofishing was carried out according to the standard EN 140 011: 2003 (Water quality – fish sampling using electrofishing), which describes the general fish counting principles, fish analytical methodology, and protocol order of completion of the main parameters which are recorded. For the electrofishing, DC electrofishing apparatus was used with a 3 kW generator and a fixed output voltage up to 500 V. Fish were only caught once in each plot. Electrofishing was carried out in an upstream direction, and demarcating nets were not used. Fishing took place in plots moving against the current in a zigzag (S) form, developing sectors from one plots edge to the other. In pothamal section of river electrofishing was carried out once along the river littoral zone (100 m), rhitral section of river 500 $m^2$ once, or repetition method – three fishing repetitions 250 $m^2$ (only Salaca river basin). Each plot was measured in length and width.

### *2.4. Area of Study Stomach Analysis*

The biological analysis of fish was conducted both during field work and in the laboratory. The caught objects of study are measured to millimetre accuracy. A separate protocol was created for stomach content composition. The stomach contents were determined for all pike, regardless of size. The fish were killed in a gentle way, and then at the edge of the plot fish section and stomach removal was carried out. After removing the stomachs they were placed in a plastic bag and fixed in 70 % ethanol solution.

Fish food objects – fish and zoobenthos representatives were defined by the Institute of Food Safety, Animal Health, and Environment “BIOR” Fish Resources Research Department, Inland Division laboratory using a stereoscopic microscope Leica S6E with a magnification of 40. The taxonomic status of food items was set to the lowest possible taxon using the following literature: fish – Kottelat and Freyhof [22]; aquatic insects – Nilsson [23].

In the laboratory, all collected stomachs had the fillings qualitative determined by dividing them into 4 classes: empty, filled little, moderately filled, filled, and a content analysis. The analysis determined the taxonomic composition and number of each item found in the stomach. The species of partially digested organisms were identified using only fragments of organisms to the lowest possible taxonomical level. The items were identified by the author, consulting with the IFSAHE “BIOR” researcher Janis Bajinskis. The frequency of which food was determined in pike stomachs was defined in percentage $\% Fi = (Ni/N) \cdot 100$, where $\% Fi$ food object percentage of incidence; $Ni$ – number of individuals with a specific food item taxa; $N$ – species = number of specimens with full stomachs [24].

### *2.5. Data Processing and Statistical Analysis*

To process the data, MS Excel computer program was used. To process and present the statistical data, MS Excel XLSTAT extension [25] was used, as well as IBM SPSS Statistics 22. To compare and evaluate the significance of the differences of the natural and channelized plot data, Kruskall-Wallis H test was used, using a 99 % confidence level. For the correlation analysis, the Pearson correlation coefficients of parametric data and Spearman rank correlation coefficients to rank the data were used in 99 % and 95 % confidence levels.

### *2.6. Cartographic Material Analysis and the Use of Other Data*

During the study, cartographic material of channelized river sections and an assessment of its impact was analysed using the University of Latvia, Faculty of Geography and Earth Sciences WMS offered maps – orthophoto 5 [26] and River basins 1970 [27]. Data on morphological alterations in rivers are taken from the Ministry of Agriculture, State Ltd. "Ministry of real estate", department of Amelioration [28], [29]. Plot descriptions and data of the number of species of fish identified are taken from the Institute of Food Safety, Animal Health, and Environment "BIOR" database [21].

## 3. RESULTS AND DISCUSSION

The analysis of cartographic material showed that of the 136 surveyed habitats, 42 % are hydromorphologically modified (straightened/channelized) sections of rivers. In total, in channelized river sections 191 pike (55 %) were harvested, lengths from 7.2 cm to 52 cm long. The collection place of pike for group comparison of channelized and natural river habitats used the non-parametric Kruskall-Wallis test. This test showed that the 23 pike of the 28 parameters described in these location groups are statistically significantly different.

Parts of the river, which are hydromorphologically modified, overall have a lower water temperature (15 °C ± 2.5 °C) compared to parts of the river that have not been modified (19.2 °C ± 3 °C). The oxygen concentration analysis showed that the straightened parts of the river show some evidence of low oxygen concentration (7.2 mg/l ± 2.7 mg/l), compared to parts of the river that have not been channelized (8 mg/l ± 1.7 mg/l). The concentration of oxygen showed a weak, negative correlation with the sections of the channelized rivers ($Rs = -0.24$; $p < 0.01$). It has been found that there is a higher pH (8.3 ± 0.4) in natural river sections, as opposed to channelized stages, 8.1 ± 0.4. Data analysis showed that there is no significant conductivity or the average depth of the differences between plots in straightened river sections and natural sections. Pike, in relation to the environmental conditions, are very tolerant [30] because of the ability to inhabit degraded habitats with very low oxygen concentration. The number of pike showed a tendency to decrease with an increase of temperature, current velocity, amount of species, and the number of pebble in the substrate. But, the number of pike increased with when the river has silt, sand, overgrowth of flowering plants (macrophytes), and if it was fully or partially shaded. It is also emphasized in literature, that the main factors influencing the spread of pike is the temperature, speed of the current, and vegetation density – the optimum temperature for metabolic processes is between 4 °C to 23 °C, and current velocity over 1.5 m/s limits the pike migration, a medium dense macrophyte vegetation provides shelter and food habitats [13], [30], [31].

The analysis of the spread of pike depending on the type of river stage showed that, there is a higher density of pike 1.4 pike/(100 $m^2$) in channelized river habitats; where as in natural river sections they are on average 0.9 pike/(100 $m^2$). Pike density weakly positively correlates with a straightened river section ($Rs = 0.36$, $p < 0.01$). The study of lowland rivers in Sweden for fish species distribution factors affecting rivers was discovered that, the most important factors influencing the spread of pike is the substrate, the barriers and the water temperature, as well as the width of the river [3].

From the 38 fish and 2 lamprey species [9] occurring in Latvian inland waters mentioned in literature, the stomach contents analysis of pike food detected 24 fish and one lamprey species: river lamprey *Lampetra fluviatilis*, spined loach *Cobitis taenia*, perch *Perca fluviatilis*, belica *Leucaspius delineatus*, dace *Leuciscus leuciscus*, stone loach *Barbatula barbatula*, Nine-spined stickleback *Pungitius pungitius*, weather loach *Misgurnus fossilis*, atlantic trout *Salmo trutta*, gudgeon *Gobio gobio*, atlantic salmon *Salmo Salar*, pike *Esox Lucius*, Tench *Tinca tinca*, minnow *Phoxinus phoxinus*, schneider *Alburnoides bipunctatus*, bullhead *Cottus gobio*, silver bream *Blicca bjoerkna*, Roach *Rutilus rutilus*, rudd *Scardinius erythrophthalmus*, catfish *Silurus glanis*, chub Squalius cephalus, prussian carp *Carassius gibelio*, three-spined stickleback *Gasterosteus aculeatus*, burbot *Lota lota*, bleak *Alburnus alburnus*. It is worth noting that, part of those species that were not found in the stomachs of the objects of study, are not present in Latvian rivers during the period of which the study was conducted – *Osmerus eperlanus* and *Coregonus lavaretus*, but some of them are rare in Latvian rivers – *Pelecus cultratus* [9].

The taxonomic analysis of pike stomach contents showed that in natural river sections, there is a significant increase in the significance of fish fauna as food. Fish were found in 81 % of individuals. In the affected sections of river, in pike stomachs, the dominant taxon was still fish, but the amount in the stomach fell to 49 %. In modified habitats, there was a significant increase in the importance of invertebrates in food, in natural sections of river invertebrates were found in 13 % of pike, but in channelized stages they accounted for 47 % of the food items. The occurrence of amphibians did not significantly change – 4 % in channelized river habitats and 6 % in natural ones. The differences in pike feeding in natural and historically channeled river sections are shown in Table 1.

Comparing the stomach content portions of the collected pike from natural and channelized river sections, it was found that there was no statistically significant difference between these indicators. Stomach contents of pike collected in the natural river sections were found to have a greater diversity of fish fauna – 19 species. In channelized sections, there were only 15 species and one species of lamprey.

The most common species of fish found in the pike stomachs were minnow (21 %), bleak (16 %), gudgeon (12 %), roach (11 %), but in morphologically transformed rivers, minnow (14 %), three-spined stickleback (11 %), bleak (11 %), nine-spined stickleback (9 %).

The pikes food was dominated by pelagic fish in both the natural (71 %), and channelized (65 %) sections of rivers. Benthic fish constitute 29 % and 35 % of pikes food. Pikes food rations are better represented by eurytopic species – 45 % in natural sections, 47 % in channelized ones. A decrease in the number of rheophilic fish species in channelized sections of river from 50 % to 35 % was noted. There is an increase in the significance of limnophilic fish in channelized sections; in natural sections they make up 5 %, where as in channelized ones, they total 18 %.

There were no noticeable changes in the amount of trophic classes found in food. The dominant class of fish in pike food, both in channelized and natural rivers, were trophic class omnivores (63 % and 58 %), then invertivores – 23 % and 27 %, and carnivorous species – 14 % and 15 %.

Analyzing feeding of pike on invertebres in cannalized sections of river, it was observed that food is dominated by insects 61 %, Malacostraca constitute for 26 %, Annelides 11 % and Molussca 2 %. However, in natural sections of rivers, three-quarters of invertebrate prey consisted of insects, and the remaining consists of Malacostraca.

It was detected that, the amount of fish fauna decreased in pike stomachs found in channelized sections of rivers, and it shows a negative correlation between channelization and the amount of food (*Rs* = –0.34), and the amount of fish food in the stomachs (*Rs*= –0.27). The amount of invertebrates found in pike stomachs increased in hydromorphologically modified river sections, but the correlation is weak (*Rs* = 0.31, $p < 0.01$).

TABLE 1. THE DIFFERENCES IN PIKE FEEDING IN NATURAL AND HISTORICALLY CHANNELED RIVER SECTIONS

| Feeding indicator | Natural | Channelized |
|---|---|---|
| Stomach fulfilment | No difference | No difference |
| Fish food | 81 % | 49 % |
| Invertebrates | 13 % | 47 % |
| Amphibians | 6 % | 4 % |
| Defined fish species | 19 | 16 |
| Defines species | *Cobitis taenia, Perca fluviatilis, Leucaspius delineatus, Barbatula barbatula, Pungitius pungitius, Salmo trutta, Gobio gobio, Salmo salar, Esox lucius, Phoxinus phoxinus, Alburnoides bipunctatus, Blicca bjoerkna, Rutilus rutilus, Silurus glanis, Squalis cephalus, Carassius gibelio, Lota lota, Alburnus alburnus.* | *Cobitis taenia ,Perca luviatilis, Leucaspius delineatus, Barbatula barbatula,, Pungitius pungitius, Salmo trutta Gobio gobio, Tinca tinca, Phoxinus phoxinus, Misgurnus fossilis, Cottus gobio, Rutilus rutilus, Gasterosteus aculeatus, Lampetra luviatilis, Lota lota, Alburnus alburnus.* |
| Feeding habitat | Pelagic 71 %<br>Benthic 29 % | Pelagic 65 %<br>Benthic 35 % |
| Residence habitat | Eurytopic 45 %<br>Rheophile 50 %<br>Limnophilic 5 % | Eurytopic 47 %<br>Rheophile 35 %<br>Limnophilic 18 % |
| Trophic class composition | Omnivore 58 %<br>Invertivores 27 %<br>Carnivore 15 % | Omnivore 63 %<br>Invertivores 23 %<br>Crnivore 14 % |
| Invertebrate taxon | Insects 75 %<br>Malacostraca 25 % | Insects 61 %<br>Malacostraca 26 %<br>Annelids 11 %<br>Mollusca 2 % |

Nevertheless, just as in this study, others [32]; [33] have shown that pike are flexible with respect to their choice of food – large invertebrate rations and a large diversity of fish species has been noted in pike population. In other studies, however, it has been found that there is a relatively small spectrum of food, and a substantial significance of invertivores in the food [34], [35]. During the study, a relatively large amount of empty stomachs, average 35 %, was noted both in channelized and natural rivers. The proportion of empty stomachs in recent studies vary between 28 % and 78 % on average, annually (28 % [36]; 50 % [34]; 50 % [32]; 33 % [35]; 54 % [33]; 78 % [37]; 58 % [18]).

Some logical connections were established in this study – if the density of fish increased in the habitat, there was a decrease in the number of pike, but, there was an increase in full stomachs and the amount of fish fauna in stomachs. However, if the amount of pike increased, there was a decrease in the amount of food in other pike and an increase in the amount of invertebrates in the food. The study revealed that, with an increase of the length of pike, there was a decrease in lesser filled stomachs, but, an increase of fish fauna and overall amount of food found in the stomachs.

Evidently, invertebrates are unable to provide/fulfill the required amount of food needs for pike, which results in unfilled stomachs, whereas fish fauna can.

A large amount of fish and species in a habitat mainly ensures its structural heterogeneity because an increase in the diversity of conditions will increase the possible food resources, hiding places, and spawning sites for fish. Rivers and river catchment alteration – artificial flooding, obstacles, dams, river straightening, and river melioration homogenizes the hydrological and geomorphological processes in the river, therefore it is imperative to preserve the natural river flow [38].

As a result of the previously mentioned anthropogenic effects, there is a decrease in environmental conditions, species diversity, and an increase in fish biomass [9], the predators have a significant effect on the populations of prey [9], [39]. In the context of this aspect of the study, significant differences appear in the feeding ecology between natural and straightened river sections, as well as in the rapids or the run. In this study it was discovered that one of the main factors affecting the pike feeding patterns is the structure of the river bed, more precisely, historical river straightening. An average decrease of 4 °C temperature was noted in hydromorphologically modified river sections, compared to those of natural ones, and lower pH values, which is partly due to the fact that a large portion of the plots in straightened rivers were located in forests – the water does not heat up as much as it would do in open areas, and decomposition (of tree litter) is taking place, which reduced the pH level.

In the straightened sections, compared to the natural sections of rivers, there was no noticeable difference in object size, stomach fullness, and the amount of empty stomachs, but there were in the foods taxonomic and ecological class content. There was an increase in the amount of three-spined sticklebackand nine-spined stickleback in pikes food in these river sections – together they accounted for 20 % of the fish prey. It is mentioned in other literature that the presence of both nine-spined and three-spined stickleback and in a fish community largely is viewed as a sign of river degradation [9], [40]. From these two facts one can deduce that, in straightened river habitats there is a rise in the amount of stickleback present, and that the pike is able to assimilate it into their food, in turn decreasing it as an unwanted species in internal waters – this confirms that pike have a "biological enhancer" role [19] in hydromorphologically modified river sections.

## 4. CONCLUSION

Comparing the channelized and natural river sections, it was found that, in historically straightened rivers, there is a lower water temperature, almost 1 mg/l lower oxygen concentration, and a lower pH by 0.2 than in natural rivers. There is a rise in pike density in habitats in straightened river sections. The taxonomic analysis of stomach contents showed that, in channelized rivers there is a substantial increase in invertebrates' significance in food. The study results show, that higher carnivore density is found in large pothamal type rivers, and in smaller, channelized pothamal type rivers.

In pothamal sections of the study areas food, there is a larger diversity in fish species than there is in rithral sections, but, rithral sections have an increase of fish fauna occurrence in stomach content. This fact confirms the optimal feeding theory (*optimal foraging theory*) – feeding fish attempt to use as little effort as possible to gain a larger amount of energy.

The *Kruskall-Wallis* test results show that, the larger part of determined and described parameters of natural and channelized sections are different, there are no statistically substantial differences in pike length, oxygen concentration, and conductivity.

There are noticeable differences in feeding between historically straightened river sections and natural sections – there is a decrease in pike feeding in rheophilic, but an increase in limnophilic fish species significance. There was no observed change in fish food trophic composition.

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