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Section: Water Engineering

Ecological status of fish community in Kairiai landfill test-ecosystem

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Abstract

The closed Kairiai landfill still remains a serious source of pollution. In some sites of Kairiai landfill test-ecosystem, water pollution exceeds "safe" concentration by 260 to 860-fold. While ecological conditions of water bodies are commonly assessed according to physical, chemical or hydro morphological criteria. The goal of this study was to investigate a long-term effect of landfill pollution on fish community's parameters and ecological status according to Lithuanian Fish Index (LFI) and Lithuanian Fish Index for Lakes (LFIL) in 2012–2013 study period. Estimates of LFI of indicate that ecological potential in the drainage channel varied from poor to bad (LFI 0.07–0.17). Variation among LFIL estimates (on average 0.45±0.003) in the Ginkūnai Pond was very limited and represented moderate ecological status of the whole water body. In Švedė Creek, LFI values (0.15–0.35) varied in relation to distance from the pond and corresponded for poor to moderate ecological potential.

Keywords: landfill; water pollution; ecological status; fish community; fish indexes.

1. Introduction

Anthropogenic impact on aquatic ecosystems in most of the water bodies of Lithuania is relatively small or absent, what maintains balance of fish communities. In stable communities, the frequency of occurrence and dominance of typical species differ: some are frequent (dominant species); the others are common (subdominant species), and the rest are rare or uncommon [1], [8]. Changes in hydrological – morphological conditions of natural water bodies consequently result in changes of natural aquatic communities. Under anthropogenic effect, typical fish communities shift to ones dominated by ecological generalists tolerant of a wide range of environmental conditions [3], [15], [16]. At present, many treatment plants are under operation to prevent the leachate from contaminating the groundwater sources of aquatic communities. However, decades and leaching induces a high stress on the landfill closures and over time those systems may leak. To find out the long-term landfill effect on fish communities in fluvial and lotic sections of Kairiai test-ecosystem, we assessed through the use of the reference condition approach (LFI and LFIL indexes) that involves testing a fish assemblage exposed to a potential stressor against a reference condition [8], [9].

2. Materials and methods

2.1. Study site

The study was carried out in Kairiai (Šiauliai district, 55° 55' 42.7", 23° 23' 42.81", WGS84) municipal landfill test-ecosystem. The landfill area is drained by a nameless channel (1 km) which diverts both surface run-off and treated leachate to the Ginkūnai Pond (112.1 ha). The Ginkūnai Pond is artificial water body with an average depth of 2.1 m, maximum depth of 4.2 m, which serves as headwater to Švedė Creek (6.5 km) (tributary of the Kulpė River 22.5 km). Whole test-ecosystem is situated in the Mūša river catchment which is characterized by intense anthropogenic pollution, channelization and natural habitat destruction, as well other factors [14]. Fish samples were collected in two sampling sites (SS) the drainage channel (SS No. 0, 1), the Ginkūnai Pond sites (No. 2, 3, 4) and Švedė Creek (SS No. 5, 6) in April 2012 and June 2013 (Table 1).

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Table 1. Characteristics of fish sampling sites in Kairiai landfill test-ecosystem

Waterbody/Sampling site No.	Sampling site start and end point coordinates (WGS84)	Sampling type/ gear length	Substrate	Depth, m	Vegetation cover (%)	Surface area, m^2
Drainage channel/ No. 0	N 55° 55.785′, E 23° 23.404′; N 55° 55.804′, E 23° 23.346′.	Electric fishing	Clay - mud	0.5	80	200
Drainage channel/ No. 1	N 55° 55.925′, E 23° 22.681′; N 55° 55.919′, E 23° 22.784′.	Electric fishing	Clay - mud	1.0	70	535
Ginkūnai Reservoir/ No. 2	N 55° 56.082′, E 23° 22.200′; N 55° 56.065′, E 23° 22.304′.	Multi - mesh gillnets/ 120 m	Sapropel	1.5	80	6000
Ginkūnai Reservoir/ No. 3	N 55° 56.517′, E 23° 22.212′; N 55° 56.568′ E 23° 22.373′.	Multi - mesh gillnets/ 220 m	Sapropel	2 - 2.5	50	11000
Ginkūnai Reservoir/ No. 4	N 55° 56.682′ E 23° 22.333′; N 55° 56.716′ E 23° 22.223′.	Multi - mesh gillnets/ 160 m	Sapropel	3 - 4	20	8000
Švedė River/ No. 5	N 55° 56.866′, E 23° 22.497′; N 55° 56.810′, E 23° 22.498′.	Electric fishing	Sand - gravel	0.3	100	162
Švedė River/ No. 6	N 55° 58.981′, E 23° 22.442′; N 55° 58.923′, E 23° 22.461′.	Electric fishing	Sand	0.3	5	157

2.2. Sample collection in fluvial section

Fish samples in Švedė Creek and drainage channel (SS No. 0, 1, 5, 6) were collected by electric fishing gear (HANS Grassl GmbH IG 200/2, Germany). The used gear and method comply with CEN guidance for fish stock assessment in rivers [11]. The basic characteristic of sampling sites is given in Table (1). Considering low fish density in sampling sites and cross sections of channels in all sites sampling was performed only once [2]. All caught fish were classified according to their species, number of individuals of each species (*N*), their lengths (TL and ST, cm), weight (*Q*, g). Fish species were also assigned to different ecological groups according to European fish classification [8, 10, and 16]. The theoretical density of individuals for each species (*N*) and biomass (*B*) of a population were calculated for a unit of area (ind/100 m² and g/100 m²) Eqns (1), (2) [8]:

$$N = y/s \times 100 \tag{1}$$

$$B = y/s \times 100 \tag{2}$$

s – Surface area of sampling site;
y – Recorded fish density or biomass of fish in sampling site.

The values obtained were additionally extrapolated to the values for area of one hectare (ind/ha and kg/ha) to enable comparison between catches in drainage channel, Švedė Creek and the Ginkūnai Pond.

2.3. Sample collection in lotic section

Fishes in the Ginkūnai Pond were obtained by standardized methods for sampling freshwater fish with multi-mesh gill nets [10]. Gill nets (length 40 m; height 1.5 m; eight panels of 5 m each with mesh sizes 14, 18, 22, 25, 30, 40, 50 and 60 mm) were evenly distributed over the whole area of the pond (SS No. 2, 3 and 4). The ichthyological analysis of caught fish was performed in accordance with generally accepted methods [17]. Caught fish were measured (*TL*, *ST*, cm) and weighed (*Q*, g). Additionally, fish density of each species (*N*), age class (AK), as well as age structure populations (K), and morphological structure (K1) of population were estimated [5]. The theoretical density of individuals for each species (*N*) and biomass (*B*) of a population were calculated for a unit of area (ind/ha and kg/ha) Eqns (3), (4):

$$N = n/pk \tag{3}$$

$$B = Q/pk \tag{4}$$

n – The number of caught fish;
Q – The total weight of caught fish;
p – Surface area;
k – Catch rate (fraction of the community, the coefficient of water bodies varies depending on the abiotic variables).

2.4. Estimation of Lithuanian Fish Indexes (LFI and LFIL)

The Švedė Creek ecological status was assessed according to Lithuanian Fish Index [4]. Lithuania Fish Index is modification of European fish index and is more suitable for local ecoregional conditions [12]. It is based on a predictive model that derives reference conditions for individual sites and quantifies the deviation between predicted and observed conditions of the fish fauna. The ecological status is expressed as an index ranging from 1 (high ecological status) to 0 (bad ecological status), which vary depending on the strength of anthropogenic impact.

Heavily modified water bodies (HMWB), such as Švedė Creek, are characterized by special regime and their environment must be assessed as ecological potential rather than ecological status [7]. The ecological potential of a water body represents the degree to which the quality of the water body's ecosystem approaches the maximum it could achieve according to its nature and use. Due to altered hydro morphological conditions heavily modified water body often do not achieve the quality targets of aquatic organisms set for natural water bodies, this way LFI values to achieve favourable condition are lower (Table 2).

Table 2. Ecological status and ecological potential classes according to Lithuanian fish index (LFI)

Type of water body	Ecological status/potential				
	High	Good	Moderate	Poor	Bad
Natural	> 0.94	0.94–0.72	0.71–0.4	0.39–0.11	< 0.11
Heavily modified (HMWB)	> 0.71	0.7–0.4	0.39–0.2	0.19–0.1	< 0.1

The ecological status of the Ginkūnai Pond was assessed according to the preliminary version of Lithuanian Fish Index for Lakes. Official ecological status assessment methods for fish in the lakes and other bodies of standing water bodies are available only in a few countries. In the countries of EC Central Baltic geographical intercalibration group (hereinafter - CB GIG), this method is still under development (in Lithuania the method is calibrated since 2011). To calculate LFIL value lakes were classified into types according to CB GIG lake common intercalibration criteria [7]. The main criteria used LFIL – the presence of obligate species depending on the type of the lakes. For this purpose, obligate species lists are made for different types of lakes. The lists are organized in terms of fish community succession in Lithuanian lakes [6] as well considering the sensitivity of different fish species [7].

3. Results and discussion

During the research, 13 species of fish belonging to four families were caught in the Kairiai landfill test-ecosystem: pikes (northern pike *Esox lucius* L.), minnows or carps (roach *Rutilus rutilus* (L.), belica *Leucaspius delineatus* Heck., bream *Abramis brama* (L.), tench *Tinca tinca* L., rudd *Scardinius erythrophtalmus* L., dace *Leuciscus leuciscus* L., bleak *Alburnus alburnus* L., crucian carp *Carassius carassius* L. and Gibel carp *Carassius gibelio* Bloch), perches (perch *Perca fluviatilis* L., ruffe *Gymnocephalus cernuus* L.), loaches (spined loach *Cobitis taenia* L.) (Table 3).

In fluvial sections of test-ecosystem, i.e. drainage channel (SS No. 0, 1) and river Švedė (SS No. 5, 6), we caught 9 fish species. With distance from landfill site fish diversity gradually increased. In drainage channel (SS No. 0) just down the treatment plant we captured 3 fish species what was the least number among all sampling sites – northern pike, gibel carp and belica. In aquatic vegetation rich downstream section of the channel before the inflow to the pond (SS No. 1) 4 fish species were present: roach, perch, tench, and belica. In Švedė Creek, below the dam (SS No. 5) fish community was represented by 7 species: northern pike, perch, roach, bleak, dace, tench and gibel carp. However, in downstream reaches of the creek (SS No. 6) we caught fewer species than in the upstream site. The structure of fish community here changed considerably with dominant rheophilic species: dace, northern pike, spiny loach and perch. In the drainage channel fish density varied from 300 kg/ha to 691.6 ind/ha and biomass from 9.7 to 25.8 kg/ha. These values are within the range obtained in natural rivers of Lithuania by Kesminas and Virbickas [13]. In Švedė Creek, down the dam fish density was relatively high reaching 2283 ind/ha and biomass varied from 50.4 to 77.7 kg/ha. In sampling site No. 6 we recorded the highest fish abundance 5860 ind/ha with biomass of 121 kg/ha (Table 3, Fig. 2) with predominant dace accounting for both highest density (76%) and biomass (80%) in the site (Figs 1, 2).

In general, drainage channel and Švedė Creek is dominated by limnophilic-eurobiontic fish species and typical rheophilic fish species such as dace, which are common to fish fauna of natural and pristine streams, begin to dominate only in the lowest reaches of the creek.

In lotic section of the Kairiai test-ecosystem, the Ginkūnai Pond, we also caught nine fish species: northern pike, roach, bream, rudd, tench, crucian carp, goldfish, perch and ruffe. In addition to listed species, common carp is as well present in the pond. Reservoir is inhabited by shallow hypertrophic water species. According to the abundance, the core of fish community here consists of 3 species: roach – perch – tench. Roach abundance in fish community was the highest from 818.2 to 1466.7 ind/ha. Perch abundance ranged from 88.9 to 600 ind/ha. Meanwhile, tench density was highest only in the shallowest part of the pond with rich aquatic vegetation (SS No. 2).

Table 3. Species composition, fish density (ind./ha), biomass (kg/ha) and estimated LFI/LFIL values (average) in sampling sites during 2012–2013 study period

Sampling site No.	Fish species	Fish density, ind./ha	Biomass, kg/ha	Distance to landfill, m	Lithuanian fish indexes for rivers (LFI) and lakes (LFIL)
0	Northern pike	100	7.05	140	0.17 Poor ecological potential
	Gibel carp	125	14.1		
	Belica	300	0.3		
	Total:	425	21.45		
1	Roach	392.5	4.754	860	0.07 Bad ecological potential
	Tench	18.7	0.9		
	Perch	46.75	9.298		
	Belica	168.2	0.648		
	Total:	626.15	15.6		
2	Gibel carp	11.1	14.7	1480	0.45 Moderate ecological status
	Tench	111.1	146.2		
	Crucian carp	11.1	4.5		
	Roach	1316.7	136.55		
	Rudd	38.85	6.35		
	Perch	94.45	20.7		
	Bream	11.1	9.6		
	Ruffe	16.65	0.35		
	Total:	1611.05	338.95		
3	Perch	169.7	45.8	2290	0.46 Moderate ecological status
	Bream	754.55	106		
	Tench	6.1	9.8		
	Crucian carp	6.1	7.95		
	Bream	12.1	6.1		
	Ruffe	6.1	0.1		
	Total:	954.65	175.75		
4	Roach	1404.15	251.1	2660	0.44 Moderate ecological status
	Perch	350	53.9		
	Bream	8.3	5		
	Ruffe	25	0.4		
	Total:	1787.45	310.4		
5	Northern pike	246.85	26.3	3100	0.15 Poor ecological potential
	Perch	1512.3	20.55		
	Tench	123.4	2.1		
	Roach	1975.3	21.5		
	Bleak	864.2	7.3		
	Dice	123.5	1.9		
	Gibel carp	123.4	1.9		
	Total:	4968.95	81.55		
6	Northern pike	63.7	15.9	7540	0.35 Moderate ecological potential
	Dice	4458.6	96.4		
	Perch	636.9	6.1		
	Spined loach	700.6	2.6		
	Total:	5859.9	121		

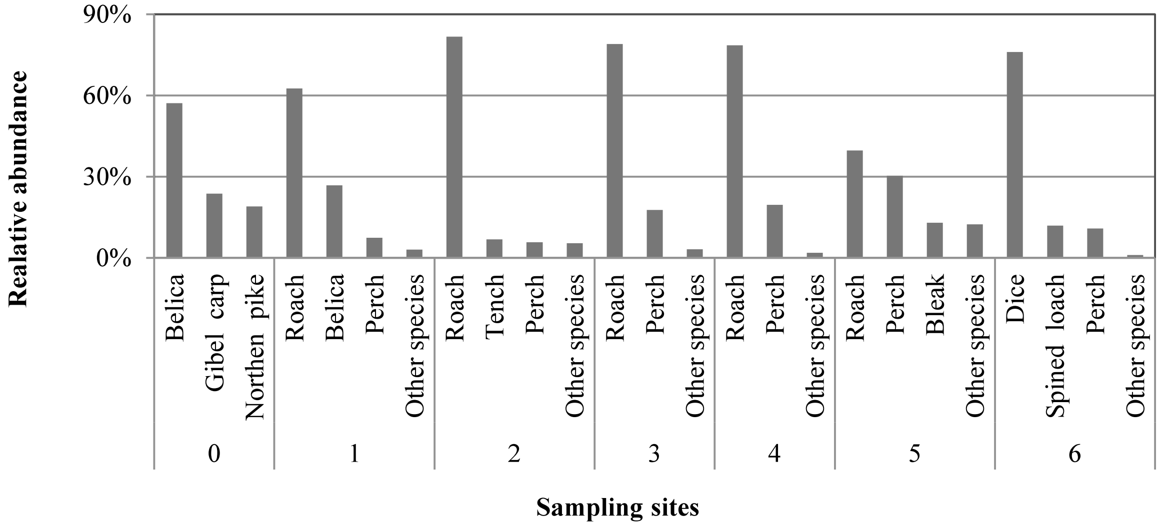

Fig. 1. Relative abundance of dominant > 5.1% fish species in Kairiai landfill test-ecosystem in 2012–2013 period

According to fish biomass, the same species emerged. The most shallow southern part reservoir of the largest fish biomass accounted for tench – from 115 to 177.4 kg/ha, roach – from 82.4 to 115.4 kg/ha and perch – from 35.5 to 45.2 kg/ha. Central (SS No. 3) and northern parts (SS No. 4) of the pond were exclusively dominated by roach - 96.6 - 287.8 kg/ha, which was followed by a several times lower biomass of perch population 38.9–68.9 kg/ha (Table 3, Fig. 2).

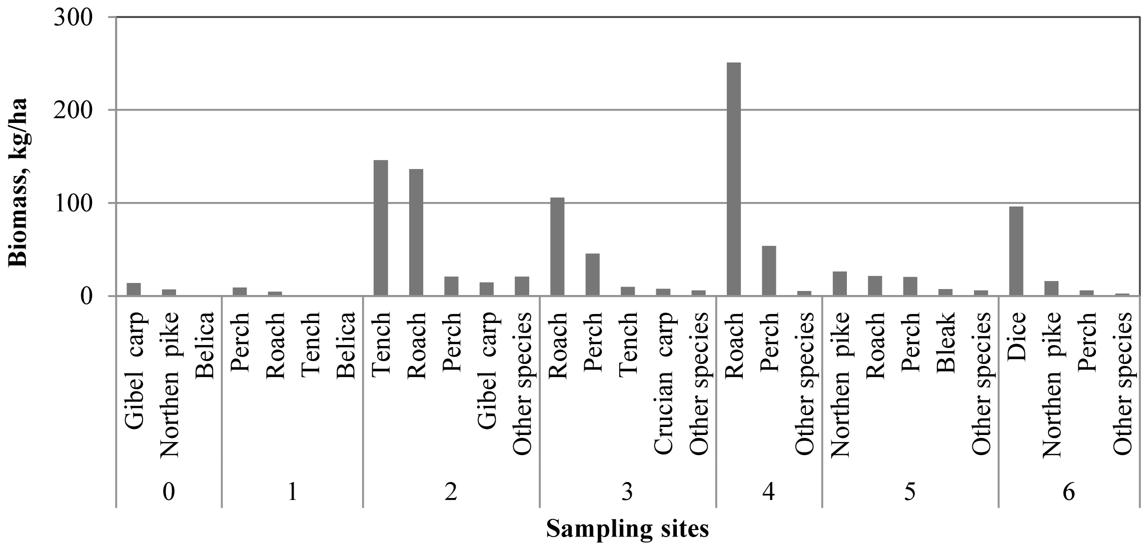

Fig. 2. Biomass (kg/ha) of different fish species in Kairiai landfill test-ecosystem in 2012–2013 period

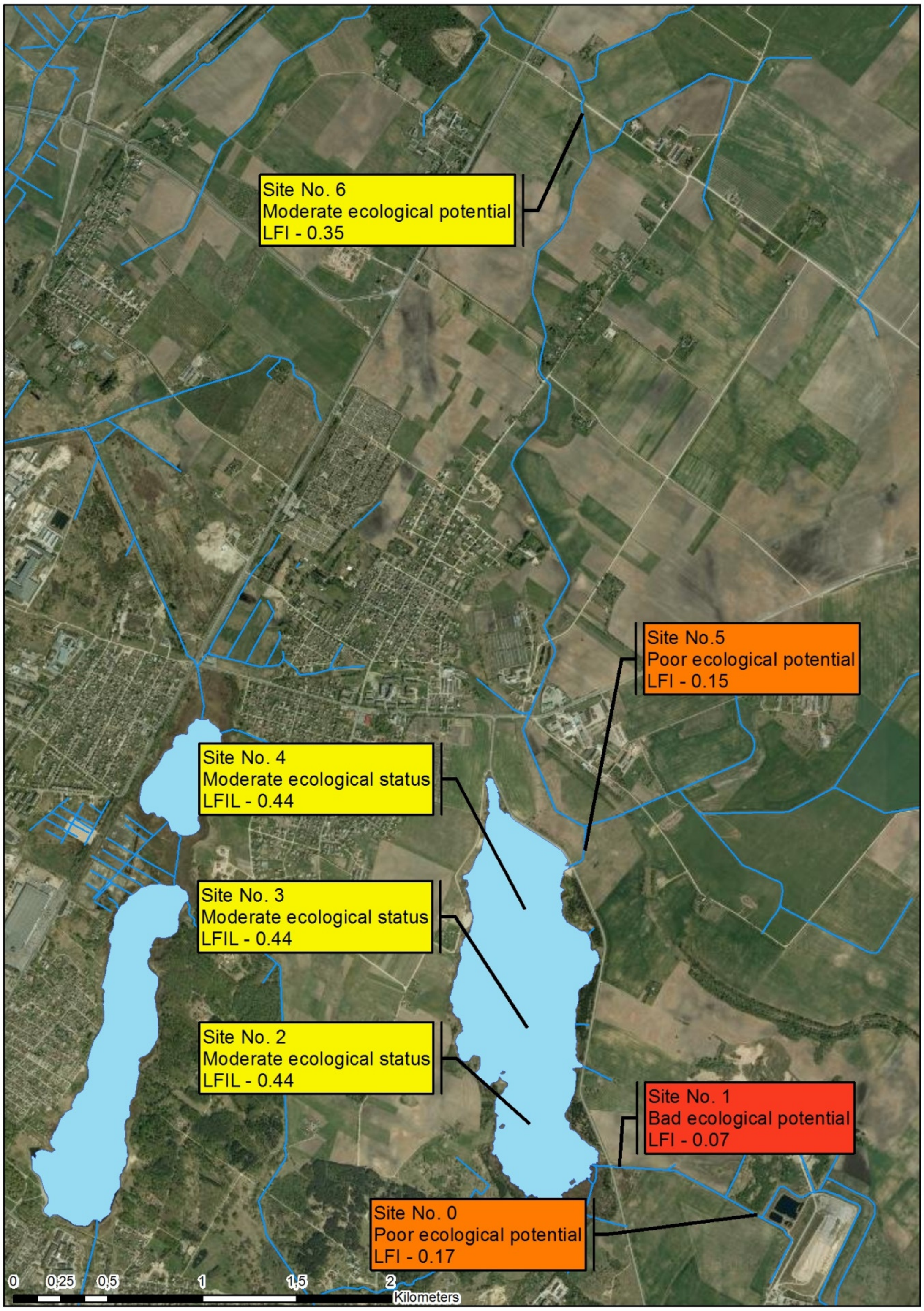

Fig. 3. According to LFI and LFIL values assessed ecological status and potential sampling sites of Kairiai landfill test-ecosystem in 2012–2013 period

The LFIL values in the Ginkūnai Pond during the study period were similar (average – 0.45 ± 0.003) and represented moderate ecological status. In the drainage channel from the treatment plant to the mouth we caught entirely limnophilic fish species tolerant of a range environmental conditions, thus resulting poor (LFI – 0.17) and bad (LFI – 0.07) ecological potentials. Švedė Creek, below the Ginkūnai dam (SS No. 5), was also dominated by limnophilic tolerant fish species resulting in poor ecological potential (LFI – 0.15). In the most downstream sampling site (SS No. 5) this potential went up to moderate (LFI – 0.35) due to occurrence and high density of typical rheophilic species (Fig. 3).

4. Conclusions

The results suggest that the most affected fish community of Kairiai landfill test-ecosystem is in the drainage channel which it is dominated by few euribiontic pollution-tolerant fish species. The Ginkūnai Pond is also dominated by euribiontic and relatively pollution-tolerant fish species, which can adapt to a variety of environmental conditions. Total fish biomass estimated in the pond is very high and varies in a quite broad range from 155.3 to 327.6 kg/ha. Such high fish productivity is affected by good nutrition and favourable spawning conditions, and absence of recreational fishing pressure on dominant species, resulting in high abundance and biomass of fish compared to other water bodies. Švedė Creek fish community gradually changes from lotic to one of the natural rivers dominated by typical rheophilic species. Such effect can be easily explained by fish transition from the pond to fish community of Švedė Creek. Fish abundance and biomass in the drainage channel was moderate and in Švedė Creek was very high.

The LFI values in the drainage channel indicate poor ecological potential down the treatment plant (site No. 0) and bad ecological potential in the lowest part of the channel (site No. 1) (LFI – from 0.17 to 0.07, respectively). As there are no obstacles limiting fish migration in the Ginkūnai Pond (SS No. 2, 3, 4) the estimated LFIL values were similar throughout the pond (on average 0.45 ± 0.003) and represented moderate ecological status. Ecological potential assessed in Švedė Creek down the dam (SS No. 5) was poor and in lowest reaches (SS No. 6) it was moderate (LFI – from 0.15 to 0.35, respectively). It is necessary to consider the effect of active fish migration and accidental transition from the pond to the creek or the channel (SS No. 1 and 5) the occurrence of limnophilic species in rivers results in a reduced fish index estimate. The assessed environmental conditions in such sites should be approached with caution as quality class can be reduced by one step.

Fish migration can also reduce severe environmental stress landfill pollutants as polluted environment usually induce avoidance response in fish. Chronic pollution has an obvious impact only on fish assemblage in the drainage channel. It could be explained by a lack of a constant flow in the channel and high water volume of the pond resulting in sedimentation of pollutants in northern part of the pond and drainage channel.

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