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RESEARCH ARTICLE

Weekly changes in prey availability for and the selective feeding of sea trout (*Salmo trutta* L.) larvae stocked in small forest streams

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Abstract. This study examined the availability of food and its selection by sea trout *Salmo trutta* L. fry in the first four weeks of life after yolk sac resorption. The food base and stomach contents of sea trout fry after release in the wild were determined. The study was performed in two small forest streams from April 25 to May 23, 2014. Macro-zoobenthos that comprised the food base for the fry were collected from the streams weekly using a bottom scraper. On the same day, the fry were captured with electrofishing gear. Analysis of the width of the benthic organisms in the food base and in the fish stomachs indicated the prey size range that the fish were feeding on. Further, the study showed that all food items found in both streams during the study weeks were also represented in the intensity of the fish: *Cyclopoida*, the larvae of *Baetidae*, *Simuliidae* and *Nemouridae*.

Keywords: salmonids larvae, restoration, food availability, food selectivity, fish growth

Introduction

As we considered in our previous study (Domagała et al. 2014), one of the ways stocking effectiveness of trout *Salmo trutta* L. larvae or fry can be improved is to ensure the availability of prey as food, mainly invertebrates, which are the main component of the diet of juvenile salmonids in the wild (Klemetsen et al. 2003, Amundsen and Gabler 2008). The main factor determining the availability of prey organisms as food is the size ratio between the predator and the prey (Wankowski and Thorpe 1979, Strandmeyer and Thorpe 1987). Larger predators consume smaller prey (Cohen et al. 1993). Thus, prey size is one of the most important factors influencing food selection by predators (Schmidt-Nielsen 1984, Reiss 1989). This factor is particularly important when undertaking the restoration of salmonids. Therefore, prior to stocking, it is important to establish the period of maximum availability and the amount and size of prey that are suitable food for juvenile salmonids and their taxonomic composition. However, in the 2014 study we investigated monthly changes in the food base and its availability to trout fry. Fish that were actively foraging in the first month of life achieved success in subsequent months. In the first month of that study, over 80% of the benthic invertebrates were available as a food base for the salmonids, which ensured their survival and development. Thus, when introducing fry, particular attention should be paid to the feeding of the fish in the first month of life, as it is crucial for their survival. We assumed that seasonal fluctuations of macro--zoobenthos body size are important in establishing the food base available to the youngest trout fry in the

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particularly difficult first month of life, and also that it was important to identify the moment when the trout fry start feeding actively. Therefore, in the present study, we decided to identify weekly changes in prey availability in the wild for trout larvae after yolk sac resorption. This is very important because of the high trout larva mortality rate in the first few days after release. Despite many attempts, and yearly stocking with larvae and fry, the survival of salmonids until the smolt stage is low (Domagała and Bartel 1997, Brown and Day 2002, Achord et al. 2007, Czerniawski et al. 2010, 2011).

The aim of this study was to determine the availability of food and its selection in the wild by sea trout larvae in the first four weeks of life after yolk sac resorption.

Material and methods

The trout larvae used in the study were six weeks old with resorbed yolk sacs (mean ± SD fork length – 25.25 ± 0.48 mm, and mean weight of 0.234 ± 0.024 g). All fish originated from the same female from the hatchery of the Polish Angling Association in Goleniów. The fish were released into two forest streams, the Chojnówka and the Trawna, on April 25, 2014. The streams are located in the Wzgórza Bukowe beech forest near the Szczecin agglomeration in northwest Poland (GPS: 53°21'09" N; 14°39'05" E). The environmental conditions of these streams differ slightly. The altitude of the headwaters of the streams is from 95 to 110 m a.s.l. No wild sea trout or other fishes occurred in either stream. Six-hundred individual trout were released into each stream along stocking sections 200 m in length. The material was released in three batches of 200 individuals in both streams; the first group was released at the beginning of the stocking section, the second in the middle, and third at the end of it.

From April 25 to May 23, macro-zoobenthos, which was the food base for the trout larvae, was collected from the streams weekly. On the same day, except on April 25, 50 trout larval individuals were captured with electrofishing gear (Hans Grassl ELT60 II, Germany). Samples of 50 fish were collected weekly throughout the experiment. The fish caught were measured and weighed. Samples of macro-zoobenthos were collected with a bottom scraper fitted with a 0.25 mm net, and they were collected from a bottom area of 0.25 m^2 at three sites in the stocking sections of the streams (i.e., one sub-sample was collected at each of the six release sites). The three macro-zoobenthos sub-samples from each of the streams comprised one sample from the stocking section of that stream. The material was fixed in a 4% formaldehyde solution and then was transported to our laboratory and identified to the level of family. The density of macro-zoobenthos was calculated per m^2. The body widths of individual macro-zoobenthos were measured, because fish larvae swallow food in one piece. The size of the largest individual macro-zoobenthos in the stomachs of the fry provided information on the size range of the organisms that the fish larvae studied could consume. Once the size of the largest organisms swallowed was established, it was assumed that lager prey were not available to the fish larvae studied.

The significance of differences in the density of macro-zoobenthos and the fork length, weight, and condition of the fish larvae in the two streams were determined with the Kruskal-Wallis non-parametric test ($P < 0.05$).

Results

Statistical analysis did not reveal significant differences in the fork length, weight, or condition of the fish between the two streams ($P > 0.05$), but differences in fork length and weight among the weeks of the study in the same stream were significant ($P < 0.05$) (Fig. 1). The density of the benthos did not differ between the two streams ($P > 0.05$). Fish stomach contents corresponded to the qualitative composition of the food base in the streams (Fig. 2). Generally, the preferred food components were the taxa that were abundant in the given stream. In the

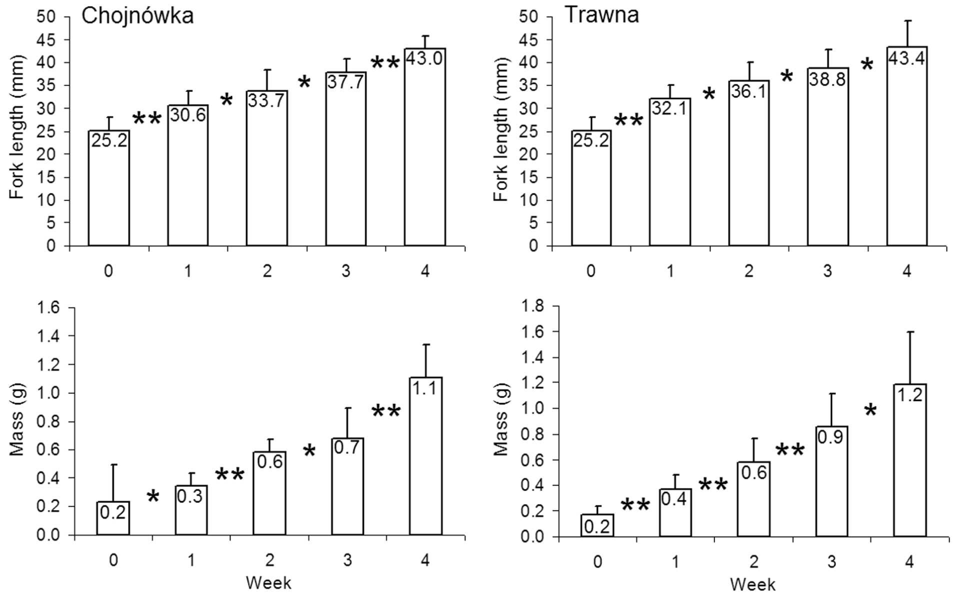

Figure 1. Mean + SD fork length and weight of fish caught in stocked sections of the Chojnówka (left column) and the Trawna (right column), n = 50. These data are derived from released fish that were sampled weekly. The asterisk denotes significant differences in fork length and weight values among weeks in the same stream; * P < 0.05, ** P < 0.01. In values of fork length and weight measured each week between two streams insignificant differences were observed (P > 0.05).

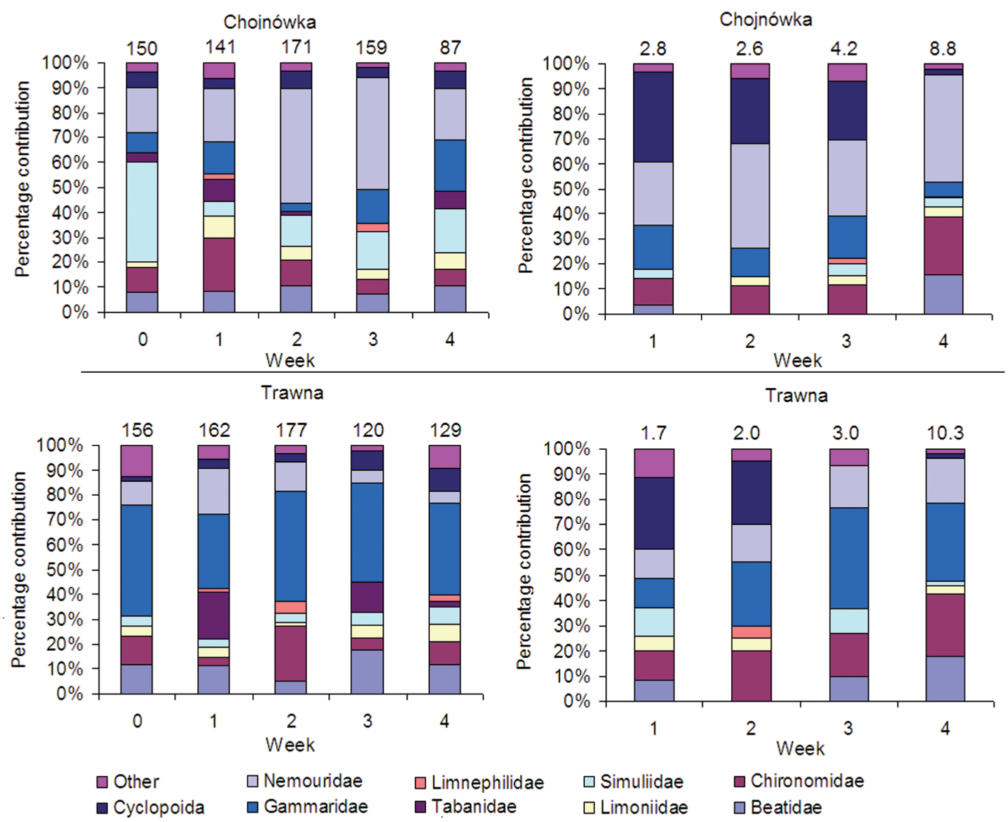

Figure 2. Percentage contribution of benthic invertebrates (food base) – left column, and the mean number of taxa in the stomachs of 50 fish in each week, n = 50 – right column. The numbers in the column refer to macrozoobenthos density – food base (ind. m^{-2}) and mean number of individuals in stomachs (ind. $stomach^{-1}$). Samples of the macrozoobenthic food base were collected in sub-samples of 0.25 m^2 monthly (one from each stocking section: upper, middle, and lower parts of the 200 m stocking area). All insect taxa observed were larvae.

first week, the stomach contents comprised small-sized taxa, while in subsequent weeks the percentage of larger size taxa increased, but this was not significant (Table 1).

Only one significant difference was observed in the number of particular groups of invertebrates in the stomachs of the fish from the Chojnówka and the Trawna (P < 0.05) (Fig. 3). According to the Kruskal-Wallis test results, in the second week the stomachs of the fish from the Chojnówka contained statistically significantly more *Nemouridae* larvae than those of the fish from the Trawna. Despite the lack of significant differences between the streams in the number of invertebrate taxa in the stomachs of the fish, the *Nemouridae* larvae were more numerous in the stomachs of the fish from the Chojnówka each week than those in the fish from the Trawna. The results observed for *Cyclopoida* are similar. Simultaneously, *Gammaridae* were more numerous in the stomachs of fish from the Trawna than from the Chojnówka except in the first week. The stomach contents of fish from the two streams also differed in the prevalence of particular taxa (Table 1). The differences diminished in subsequent months, e.g., in the first week *Chironomidae* larvae were found in 60% of the fish from the Chojnówka, while they were found in 100% of the fish from the Trawna. In the last week of the study, these figures were 75 and 100%, respectively. The most similar prevalence of invertebrates in the stomachs of the fish was of *Limoniidae* and other invertebrates.

The analysis of the width of the benthic organisms in the food base and in the fish stomachs indicated that *Baetidae* larvae, *Cyclopoida*, and almost all *Simuliidae* and *Nemouridae* were available as food in both streams each week (Fig. 4). The majority

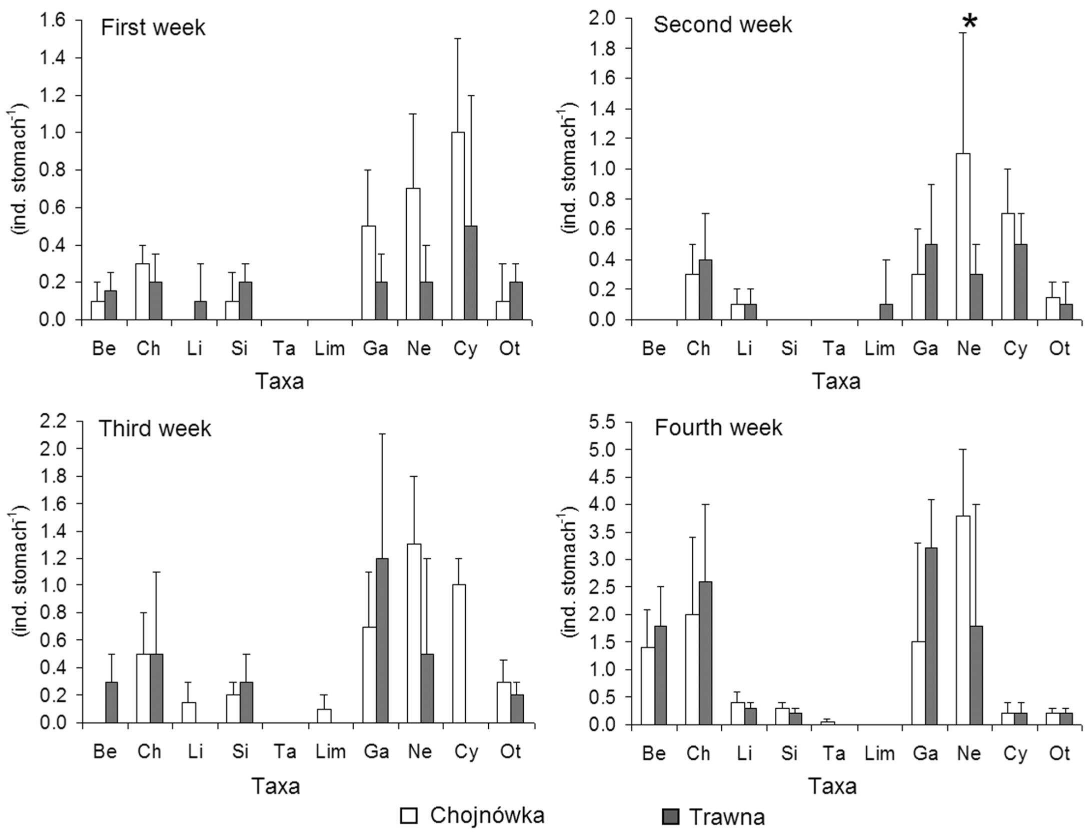

Figure 3. Mean + SD of number of taxa individuals in the stomachs of released fish (n = 50) sampled weekly from stocked sections of the Chojnówka and the Trawna. Significant differences in number of taxa in fish stomachs between the two streams are marked with *P < 0.05. Be – Beatidae, Ch – Chironomidae, Li – Limoniidae, Si – Simuliidae, Ta – Tabanidae, Lim – Limnephilidae, Ga – Gammaridae, Ne – Nemouridae, Cy – Cyclopoida, Ot – other.

Table 1
Prevalence (%) and body width (BW) (mm) of invertebrate taxa in stomachs of fish (n = 50) sampled weekly from sections of the Chojnówka and Trawna into which stocking material was released

		Chojnówka				Trawna			
		Week				Week			
Taxa		1	2	3	4	1	2	3	4
Beatidae	Prevalence	20	-	-	13	13	-	20	13
	BW mean	0.92	-	-	0.87	1.87	-	1.23	0.56
	BW min	0.26	-	-	0.86	1.68	-	0.43	0.11
	BW max	1.11	-	-	0.87	2.05	-	1.78	0.87
Chironomidae	Prevalence	60	60	80	75	100	100	100	100
	BW mean	0.45	0.55	0.32	0.52	0.31	0.38	0.35	0.38
	BW min	0.35	0.42	0.26	0.22	0.10	0.12	0.09	0.14
	BW max	0.54	0.72	0.46	0.80	0.79	0.65	0.85	0.87
Limoniidae	Prevalence	-	30	35	40	25	30	-	35
	BW mean	-	0.48	0.57	0.62	0.59	0.68	-	0.64
	BW min	-	0.27	0.32	0.35	0.34	0.44	-	0.38
	BW max	-	0.68	0.82	0.88	0.83	0.92	-	0.89
Simmuliidae	Prevalence	15	-	31	33	18	-	34	35
	BW mean	0.80	-	0.71	0.49	0.46	-	0.68	0.72
	BW min	0.36	-	0.35	0.21	0.30	-	0.47	0.49
	BW max	1.24	-	1.22	0.78	0.62	-	0.89	1.02
Tabanidae	Prevalence	-	-	-	-	-	-	-	18
	BW mean	-	-	-	-	-	-	-	1.55
	BW min	-	-	-	-	-	-	-	1.30
	BW max	-	-	-	-	-	-	-	1.80
Limnephiplidae	Prevalence	-	-	12	-	-	15	-	-
	BW mean	-	-	0.79	-	-	0.80	-	-
	BW min	-	-	0.46	-	-	0.57	-	-
	BW max	-	-	1.11	-	-	1.02	-	-
Gammaridae	Prevalence	50	40	70	100	100	100	80	100
	BW mean	0.96	0.79	0.52	1.05	1.15	0.89	0.93	0.77
	BW min	0.32	0.35	0.31	0.35	0.57	0.32	0.89	0.35
	BW max	1.59	1.22	0.82	2.17	1.76	2.18	0.96	2.36
Nemouridae	Prevalence	53	80	38	17	27	70	30	67
	BW mean	0.76	1.03	0.73	0.84	1.05	0.90	0.75	0.90
	BW min	0.14	0.31	0.36	0.37	0.67	0.26	0.62	0.46
	BW max	1.40	1.69	1.05	1.30	1.77	1.76	0.86	1.27
Cyclopida	Prevalence	40	30	34	20	20	10	-	5
	BW mean	0.16	0.21	0.20	0.22	0.14	0.18	-	0.19
	BW min	0.10	0.10	0.12	0.20	0.10	0.12	-	0.13
	BW max	0.22	0.31	0.27	0.23	0.18	0.23	-	0.25
Other	Prevalence	13	18	13	27	8	13	17	13
	BW mean	0.75	0.71	1.16	1.44	0.40	0.53	0.72	1.20
	BW min	0.63	0.44	1.05	0.46	0.19	0.27	0.56	1.18
	BW max	0.86	0.98	1.27	2.42	0.60	0.79	0.87	1.21

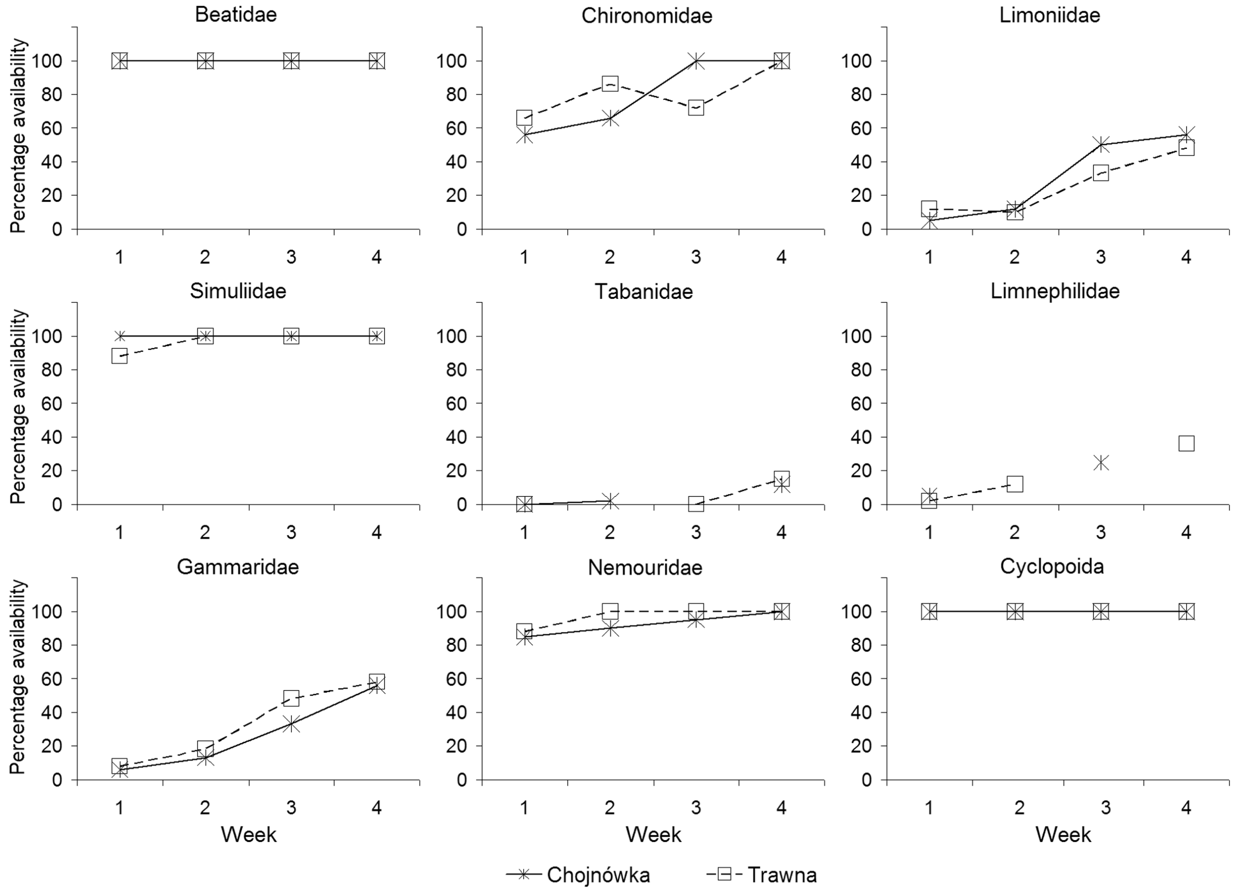

Figure 4. Weekly rates of the percentage availability of the most abundant taxa of the food base for trout larvae in the stocked sections of the Chojnówka and the Trawna.

of *Chironomidae* larvae were also available as food in each week of the study. The availability of *Gammaridae* as food ranged from 6 to 58% in different weeks, which is related to the developmental cycle of these crustaceans. *Limoniidae* larvae were available in relatively high abundance from the third week, while *Tabanidae* larvae were not normally available in the first month after stocking.

Discussion

Food base

Although differences in macro-zoobenthos density were insignificant, the dominance of some taxa differed in the two streams. Differences in the benthic food base between the two streams is explained by their slightly different morphological conditions. The taxa occurring in the streams were typical of spring benthos (Czerniawski et al. 2007) and flowing waters (Elliot 1967, Angermeier 1982).

Fish growth

The fork length, weight, and condition factor values are similar to the results reported for other stages and species of salmonids at the same age (Różańska 1961, Amundsen and Gabler 2008, Domagała et al. 2014, Czerniawski et al. 2015). The lack of significant differences in the condition factor values between the streams and the high similarity in the growth of the fish from both streams means that both streams offer sufficient food and environmental conditions for the growth of fry at the given density. The significant differences in the fork lengths and weights of fish among the weeks of the study in the two streams indicate good trophic conditions for fish growth.

Stomach contents

Salmonid fry usually prefer larval *Ephemeroptera*, *Plecoptera*, and *Diptera* as their prey, while larval *Coleoptera* and *Gammaridae* are also relatively abundant among the prey items consumed (Strandmeyer and Thorpe 1987, Amundsen and Gabler 2008, Domagała et al. 2014). The composition of the food base was usually reflected in the stomach contents of the fish studied, and the dominant taxa at a given site were also most abundantly represented in the stomach contents. Generally, the most preferred food in both streams was *Neumoridae* larvae, *Chironomidae* larvae, and *Gammaridae*. The prevalence of the largest taxa (e.g., *Limoniidae* larvae and *Chironomidae* and *Gammaridae*) was also higher in subsequent weeks. This pattern is the same as the one we observed in our previous study on the selective feeding of trout fry in the first four months of their life cycle (Domagała et al. 2014).

Juvenile salmonids prefer consuming food from the water column and the water surface rather than from the bottom in given watercourses (Strandmeyer and Thorpe 1987, Johansen et al. 2010). However, similar to our previous study, analyses of the contribution and frequency of particular food components indicated that in the Chojnówka the fish preferred taxa from the group of invertebrates that made the highest contribution to those carried by currents (*Nemouridae* larvae, *Cyclopoida*) (Johansen et al. 2010), while in the Trawna the fish preferred *Gammiridae* and *Chironomidae* larvae, which were the most numerous in the benthos (Czerniawski et al. 2007, 2009). However, these differences are relatively rather small. Since the streams studied were quite shallow, the fish came into more frequent contact with the bottom and its benthic organisms, which were easier to tear off the bottom than to do so in the water column. Strandmeyer and Thorpe (1987) conclude that juvenile salmonids feed mostly on organisms drifting on currents and less frequently on benthic species. While in the present study we did not sample or analyze the composition of drifting invertebrates, based on our previous research, we contend that benthic samples were sufficient for assessing the food that was actually available to the trout fry.

Food size

As the fish increased in size in subsequent months, the contribution of larger food components increased; however, the differences between the first and fourth week were not as large as in our previous study that examined these differences among months (Domagała et al. 2014). The larger sized food components consumed by larger fish suggests that the difference in body size and not food selectivity is the main determinant of food relations in freshwater trophic webs (Warren and Lawton 1987). The small differences in prey body widths indicate that in the first month after fish yolk sac resorption, the sizes of all components of the food base (zoobenthos) are similar in each week and that they represent the majority available to trout larvae. According to our previous study (Domagała et al. 2014), this pattern changes in the second month after yolk sac resorption. Undoubtedly, this is associated with environmental changes in the spring, when higher temperatures and the increased abundance of other invertebrate prey positively affected juvenile trout growth. However, we are aware that these conclusions are speculative, because of possible inaccuracies in the analysis of a drifting food base.

Food availability

The analyses of prey body widths in the food base and in fish stomach contents showed that weekly the fish found appropriately sized prey with widths smaller than those of their mouths. The majority of taxa in the food base were available for the fish in each week, so their mouth size permitted consuming the majority of organisms available. Our previous (Domagała et al. 2014) and present studies indicate that, in the food base, only *Tabanidae* larvae are too wide to be available to trout larvae as food. Rarely could juvenile trout consume *Tabanidae* larvae in the fourth week or in the second month after yolk sac resorption. In the majority of cases, *Gammaridae* and *Limoniidae* larvae are also unavailable as food for the first two weeks after yolk sac resorption. The highest contribution in the stomachs and the availability of *Gammaridae* as food for trout larvae in the third and fourth weeks could be related to the developmental cycle of these taxa and also to the fish consuming the smallest individuals. In conclusion, in each month studied, both streams offered taxa that were available to the fry as food and could sustain optimum larval growth.

From the first week after yolk sac resorption, the trout larvae actively fed on the invertebrates available in the wild. However, Domagała et al. (2015) contend that trout larvae can live without food even for three weeks following the resorption of two-thirds of the yolk sac without any notable losses and that the best moment to release trout larvae into the wild is in the period from the resorption of two-thirds of the yolk sac until the third week after resorption, which is one week following full resorption. In each week of the present study, the main components of the stomach content were *Nemouridae* and *Chironomidae* larvae; however, in the first week available prey included larval *Baetidae*, *Simuliidae*, *Nemouridae* and *Cyclopoida*. In subsequent weeks, the number of larger taxa, such as *Chironomidae* larvae and *Gammaridae*, increased in the stomach contents. Fish prey selectivity by depended on the food base available. Most often the fish consumed taxa of suitable body size for their mouths, which dominated the zoobenthic food base. Consequently, in each week of the study in both streams, trout larvae had suitable food bases to ensure their survival and development. It appears that the fish that were actively foraging in the first week of life achieved success in subsequent weeks. The highest percentage availability of invertebrate prey from the majority taxa was noted in the third week after yolk sac resorption. Therefore, before releasing trout larvae, it is recommended to rear them for two weeks after yolk sac resorption on live food (Czerniawski et al. 2010, 2015). Before the release of stocking material, the food base available at stocking sites should be evaluated. Our studies focus on restoring salmonid populations in locations where they cannot reproduce because there are no appropriate spawning sites or there are barriers to migration, and where restoration, other than stocking with hatchery fish, is impossible. Obviously, we are aware that the best way of restoring salmonid populations is to facilitate natural adult salmonid reproduction by ensuring they have the appropriate conditions for natural spawning.

Author contrubutions. J.D., R.C., T.K. designed and performed the experiment, J.D., R.C., T.K. analyzed the data, J.D., R.C., T.K. wrote the paper.

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